"THERMAL COMFORT SENSATIONS AND PHYSIOLOGICAL REACTIONS IN RELATION TO VARIATIONS IN INDOOR CLIMATE."

THESIS

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ABSTRACT OF THESIS

"THERMAL COMFORT SENSATIONS AND PHYSIOLOGICAL REACTIONS IN RELATION TO VARIATIONS IN INDOOR CLIMATE."

The present study formed part of a programme of research on requirements for comfort and health in houses of modern design. It is particularly concerned with the changes in air temperature and humidity which may arise in dual purpose living rooms during the performance of family clothes washing, the physiological effects of such changes on the occupants and the definition of the measures necessary for the control of room climate and the prevention of thermal discomfort, excessive fatigue and heat stress.

In view of the widespread use of gas wash boilers in houses and the fact that such appliances are commonly installed without flues for the removal of excess heat and the products of gas combustion to the outside air it was decided to carry out full-scale experiments in a room of modern type specially constructed for such studies.

The early part of this investigation dealt with the development of physical methods for the rapid assessment of changes in room climate and the application of those methods to studying the build up and decay of temperature and humidity in rooms when a gas wash boiler is operated according to common practice. Data obtained indicated that a minimum air change rate of approximately 18,000 cubic feet per hour, namely 18 room air changes are necessary for the maintenance of a comfortable working atmosphere in a room of 1,000 cubic feet capacity whilst domestic washing operations are in progress.

These experiments were followed by a physiological and physical user-test study in which techniques were developed and used to assess the circulatory changes and subjective reactions of a number of housewives who participated as working and control subjects. The results reinforced the findings of the preliminary physical investigation.

Finally, a series of controlled experiments were conducted on a number of subjects in an air conditioned room to test the validity of the correlation between the physiological indices employed in these user-test experiments to assess thermal stress, namely, the Crampton Index, the forehead skin conductivity and the subjective thermal sensations of heat, moisture and freshness with the environmental thermal conditions. The effect of the performance of muscular work on the changes in these indices was also determined. The findings lent full substantiation to the conclusions drawn from the user-test experiments in kitchen living rooms.

Attention is drawn to the preliminary findings of a field survey in which the domestic routines adopted by a number of housewives were studied.

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Introduction

Throughout life man is subjected to variations in outdoor and indoor climate which influence physiological processes and evoke sensations of thermal comfort or discomfort, or fatigue.

Problems of comfort and health in dwellings are not only concerned with the determination and maintenance of indoor climatic conditions which satisfy physiological and psychological requirements during leisure hours, but must also include the control of environmental factors which affect those members of the family whose daily work centres in the home. Thus in the case of the mother with a family of young children, such recurring activities as the preparation of meals and the washing, drying and ironing of clothes create problems of indoor climatic control which are to a large extent independent of the outdoor climate, although at times the weather may assist or hinder performance.

When operations of this type have to be carried out in small rooms, such as a kitchen annex or a living room kitchen which serves a dual purpose in many houses of modern design, changes in room climate may rapidly develop owing to the heat and moisture imparted to the air by the cooking or washing appliances used. Excessive heat, humidity and condensation give rise to adverse physiological reactions and subjective sensations and when coupled with odours, and the products of combustion of coal gas in cookers and boilers, may materially affect home comfort if they penetrate to other parts of the house.

When active muscular work is performed, the individual's rate of body heat production increases considerably. Physiological requirements for body temperature control demand that the rate of heat loss should correspond with heat production and any substantial rise in the temperature and humidity of the air may cause sensations of thermal discomfort and stress. The present study is concerned in particular with the changes in room climate due to washing operations and their physiological effects on the occupants.

The extensive surveys which have been carried out in industry have demonstrated the relationship between the thermal characteristics of the environment of work, physiological reactions, subjective sensations, accident incidence and output, but as yet it appears that research of this type has not been fully extended to the home environment. However, S.C. Hite and J.L. Bray[1] (1948) at Purdue University, carried out a research programme for the American Gas Association upon the problem of home humidity control. The objects of their research were to determine the various sources of water vapour and the relative importance of each within the home, and possible methods of moisture control.

In their investigations the living habits of the average American family of four were studied. They were able to show that as much as 55 lbs. of water vapour were liberated on a wash day. They studied not only the intermittent, but also the constant sources of moisture, clothes washing and drying, cooking, floor mopping, the human contribution and even the effect of the presence of house plants. In addition they showed that rates of from 150 to 300 cu. ft. of air removal per minute sufficed to provide effective moisture control when the ventilating system was placed in the immediate vicinity of the domestic appliances used.

W.T. Miller and F.B. Morse[2] (1950) also working at Purdue University, have published a bulletin discussing the sources of moisture in homes, the damage and maintenance cost that severe moisture problems cause, together with some recommendations for solving these problems. Their studies were undertaken because many complaints had been made by residents in Indiana who were spending thousands of dollars each year because of excessive moisture in their houses.

Little, if any, attention has however been paid to the personal reactions of the individuals whose domestic responsibilities require them to work under changing conditions of temperature and humidity which stimulate physiological reactions and give rise to sensations of thermal discomfort. Subjective sensations of heat, moisture and freshness and physiological reactions, such as sweating and circulatory changes while working under such conditions should provide a scientific basis for determining the nature and extent of the control of heat and moisture necessary to meet requirements for comfort and health in the home.

That the need for the special control of heat and humidity in kitchens has been realised is evident from the fact that in Post War Building Studies No. 19[3] drawn up by the Heating and Ventilating Committee of the Building Research Board and the subsequent Codes of Practice[4] [5] the following recommendations for kitchen climate were made:-

(i) Temperature. A minimum equivalent temperature of 60°F. No upper limit is stated for comfort and physiological well-being whilst cooking ~~or~~ washing is in progress.

(ii) Humidity. Adequate ventilation, preferably controllable, should be provided to keep the humidity below 70% at all times.

(iii) Ventilation. Whilst cooking for not more than six persons is in operation a minimum air change rate of 2,000 cubic feet of air per hour is recommended. It is further suggested that solid fuel flues should be provided in all kitchens to reduce the penetration of odours and steam to other parts of the house.

When planning the present investigation it was decided that in the first instance it was necessary to survey the methods available for the assessment of the physical characteristics of room climate and determine experimental techniques which could be carried out without interfering with the routine performance of specific domestic tasks by the working subjects. It was also essential to review the techniques which had been used for assessing the physiological reactions of working and resting subjects to changes in the thermal environment and select those appropriate for the purpose of the investigation bearing in mind that these should involve minimum distraction or disturbance to the subjects.

Having regard to the fact that the ultimate objective of the study was the establishment of a scientific basis for formulating recommendations for the use of the provisions for ventilation, cooking and washing which are installed in houses of modern design, it was clearly essential that the experimental work must be carried out in rooms of the type and size approved by housing authorities. Fortunately three rooms of the type required were available at the Field Test Unit of the Building Research Station, and it was decided to use the centre room, Fig.21, for the experiments as it was a living room kitchen in which washing and cooking appliances were already installed.

It was accordingly planned to carry out the programme of research in the following stages:

(i) Physical. The investigation of methods for the rapid assessment of thermal changes in the room climate, air temperature, humidity, mean temperature of surroundings, air movement and ventilation.

(ii) Pilot experiments with working subjects to determine appropriate techniques for the assessment of their physiological reactions and subjective thermal sensations during the performance of specified domestic tasks. These pilot studies would include the use of physical methods determined in Stage (i).

(iii) Full scale User-Test experiments with working and control (resting) subjects to determine the relationship between changes in room climate and the physiological reactions and subjective thermal sensations of the subjects.

(iv) Laboratory experiments in an air conditioned room with temperature and humidity controlled at various levels in order to test the validity of the correlation between physiological reactions, subjective sensations and the changes in room climate, indicated by the findings of (iii).

(v) Field survey in houses and flats to collect data of the changes in room climate which occur during washing and cooking operations.

The preliminary phase of this investigation was of a purely physical nature. Before a study of variations in room climate due to domestic operations and changes in subjective thermal sensations and related physiological reactions could be undertaken, it was essential to design and develop apparatus which would rapidly and accurately measure the changes in temperature and humidity that occurred.

Such determinations are made difficult in many cases where the usual methods cannot be employed. Limited space and the necessity for taking readings at remote corners eliminate the use of the sling psychrometer. This instrument has been widely used in environmental studies but is unsuitable for assessing the vertical and horizontal distribution of temperatures and humidities in a small room or kitchen. The sampling method of the Assmann, because of the turbulent air motion it sets up is also not suitable where it is essential to maintain undisturbed the existent conditions of air movement. Small scale hair thermo-hygrographs and instruments functioning on the principle of the variation of electrical conductivity of certain hygroscopic materials for the measurement of relative humidity may be used to advantage in some instances, but such instruments are subject to unfavourable variations in calibration and some time must be allowed for them to reach equilibrium. This can be as long as 30 minutes. Since it was essential in this study to be able to measure sudden changes in environmental conditions these instruments were clearly not suitable and

CHAPTER I

The development of a technique for the rapid assessment of room climate

Introduction

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Therefore, the problem was to develop a remote reading method for measuring rapidly both the wet and dry bulb temperatures from robust and easily reproducible elements situated at several points in a room. Such a system would have to be linked to a single measuring unit and therefore the possibilities of using a number of thermocouples connected through a reference junction and a selector switch to a potentiometer was considered.

In 1929, E. Griffiths, J.R. Vickery and N.E. Holmes[6] used a psychrometer consisting of thirty-three wet and dry copper-constantan thermocouple junctions connected in series as a remote reading method of observing the humidities obtaining in cold water storage holds on board ship. M. Okada[7] (1931) and J.R. Lanning[8] (1932) have also used thermocouple circuits for the assessment of humidity distributions in enclosures. However, more recently, F. Pasquill[9] (1949) developed a technique for assessing the wet and dry bulb temperatures in a study of humidity profiles above the ground in certain agricultrual experiments. The elements had to be robust for field work and such a requirement prohibited the use of the fine thermocouple wire. Consequently he used 28 gauge copper-constantan wire. It has been shown (R.W. Powell[10] (1936)) that the need for forced ventilation of the wet thermocouple is increased as the diameter of the wire used is increased and that errors in the wet bulb temperature of the order of +0.6°F. are introduced by using the still air wet bulb depression for wires of this diameter.

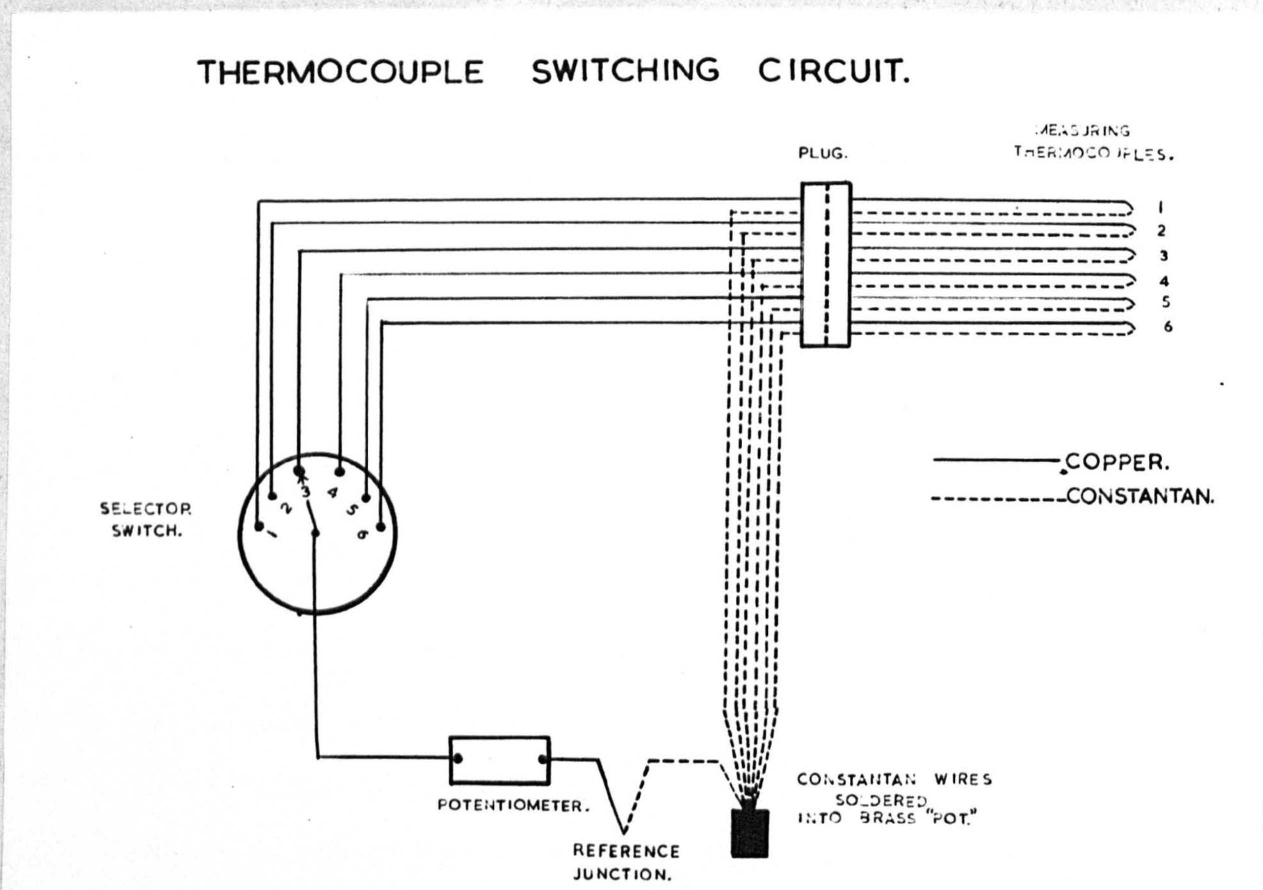

THERMOCOUPLE SWITCHING CIRCUIT.
PLUG.
MEASURING THERMOCOUPLES.
1
2
3
4
5
6
COPPER.
CONSTANTAN.
SELECTOR SWITCH.
1
2
3
4
5
6
POTENTIOMETER.
REFERENCE JUNCTION.
CONSTANTAN WIRES SOLDERED INTO BRASS "POT."

FIG. 1.1.

In order to achieve sufficient aspiration of the elements they were plased inside cylinders of small diameters. By this method an air velocity of at least 2 meters per second past the themocouples, which was needed to give a maximum depression, was obtained with little displacement of the ambient air.

Therefore it was decided to adopt such a technique to minimuse the air displacement due to sampling for surveying changes in room temperature and humidity.

Experimental Methods

(a) Thermocouple circuit

To facilitate easy construction of the switching circuit, 32 gauge copper-constantan thermocouples were used. The terminals of the potentiometer were of copper which necessitated copper leads to eliminate spurious sources of e.m.f. If pairs of wires, excluding copper were to be used in a system containing N thermocouples, then (N + 1) reference junctions would be necessary. However, with copper as one material component of the thermocouples only one reference junction is necessary, irrespective of the number of elements required.

The circuit used (see fig. 1.1) consisted essentially of six constantan wires soldered into a brass "pot", emerging from which was a single constantan wire which formed a reference junction in melting ice with a copper wire. This lead, through a potentiometer terminated at the central pole of a six-way switch. The six copper leads leaving the switch were silver-soldered to six points on one side of a twelve point plug. Soldered to the remaining six points were the six constantan wires from the brass "pot". This part of the circuit, which included the potentiometer and reference junction was contained in a box measuring $21\frac{1}{2}$" x 10" x 12". In this way the apparatus was portable.

To the other side of the plug were soldered six copper and six constantan wires which formed the measuring thermocouples. In all, four such plugs were made up, two with six foot leads and two with twelve foot leads. The two elements were silver soldered together to give a strong junction.

Calibration. It was found necessary to anneal the couples by immersion overnight in boiling water and this procedure was repeated on several consecutive days before consistant calibrations were obtained. The couples were calibrated in circuit with the reference junction in melting ice and the measuring thermocouples immersed in a thermos flask containing water, the temperature of which together with that of the reference junction was determined by standard immersion mercury-in-glass thermometers. Thermo electric e.m.f's. were recorded at 5°F. intervals from 32°F. to 107°F. for all twenty four couples.

The calibration was linear over the useful temperature range of 40°F. to 90°F., the thermo electric e.m.f. being 0.022 millivolts per °F.

Sensitivity. No movement of the galvanometer needle of the potentiometer could be detected by eye for a movement of the fine variable resistance equivalent to 0.0025 millivolts in either direction. Thus each reading of temperature was subject to an error of ±0.1°F.

A necessary precaution, which involved a delay of from one to two minutes was necessary each time a different plug of six couples was inserted in the circuit. This was to ensure that if a temperature

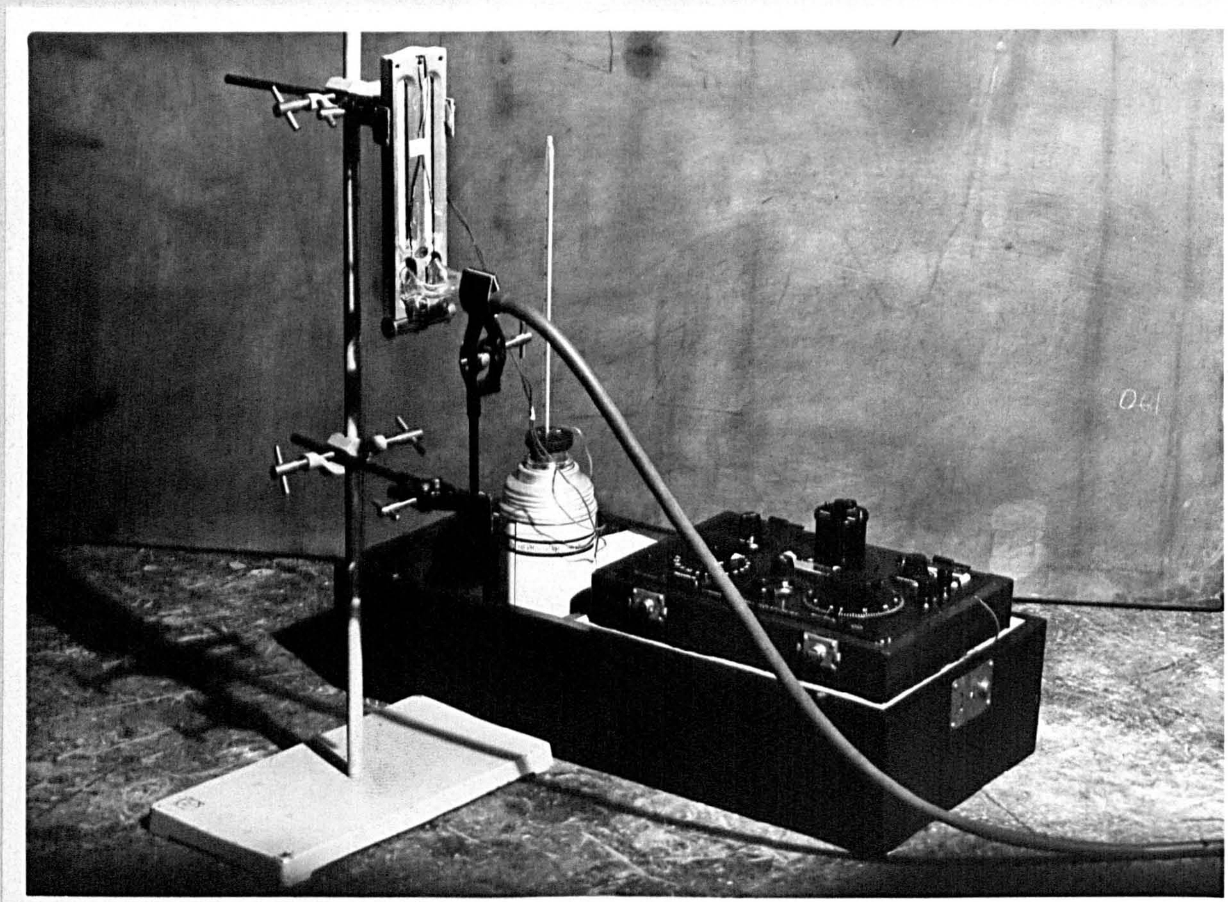


FIG. 1.2

Apparatus for the Measurement of Environmental temperature and humidity.

gradient existed across the two components of the plug it would have, for all practical purposes, approached zero, thus eliminating a possible spurious source of electromotive force prior to taking a series of six readings.

(b) The Wet and Dry Bulb Elements.

A method was evolved incorporating the main principle of Pasquill's method but which made use of ready made, easily available and robust components. It consisted essentially of a rigidly supported whirling hygrometer with a thermocouple attached to the bulb of the D.B. thermometer and a second thermocouple inserted to a depth of 1 cm. (greater than 50 times the wire diameter) between the bulb and the wetted wick of the W.B. thermometer. The elements were placed as near the plane of the elliptical orifices, which measured 2 cm. by 0.5 cm., of a glass Y-shaped tube, (diameter 0.75 cm.), which through a length of rubber tubing was linked to an electrically operated Assmann psychrometer the fan of which provided the necessary aspiration of the elements. This was a relatively simple method for the remote assessment of wet and dry bulb temperatures with the advantage that in the possible event of a failure during an experiment of the thermocouple circuit, the observer could resort to measuring the temperatures from the normal small thermometers of the whirling hygrometer. Further tests showed that sufficient ventilation could be achieved by the fan of the Assmann psychrometer for the simultaneous aspiration of three such elements. The couples were electrically insulated by the application at the junction of a dilute solution of nicol label varnish and acetone. The reservoir provided for distilled water and the normal type wicks supplied with whirling hygrometers were used and in this way the wet elements could be kept moist without attention for at least eight hours.

The Emissivity of the Dry Bulb Element. A solution of acetone and nicol label varnish was used as an insulator because a very thin layer could be applied and in this way, its application did not materially add to the thermal capacity of the thermocouples. However, it was necessary, when use was to be made of the insulated couples for the measurement of dry bulb air temperatures to ascertain the effect on the surface emissivity. This was done in the following way.

Two thermocouples, both silver soldered, one insulated and the other bare but highly polished were suspended together with a silvered globe and silvered kata thermometers approximately three feet from and exposed to the radiation from a two kilowatt heater. In this way, the intensity of radiation to which the thermocouples were exposed was at least equal to that to which they would be exposed in experiments in kitchen climate studies.

After half an hour, when the globe and silvered readings were seen to be steady, 10 observations of the two thermocouple e.m.f's., the globe and the silvered thermometer readings were taken and the air velocity was computed from the cooling times of the kata thermometer.

The radiation gain by the globe thermometer (Hr) is given by

$$Hr = E\ S\ \ (Ts^4 - Tg^4)\ \text{B.T.U./sq. ft./hr.}$$

Ts can be calculated from the convection loss - radiation gain equilibrium equation for the globe thermometer:-

$$Es\ (Ts^4 - Tg^4) = 0.169 \times 10^9 (v)^{\frac{1}{2}} \times (tg - ta)$$

E = emissivity of the globe surface = 0.95

S = Stefan's constant on the Farenheit scale = 1.73×10^{-9}
(Fishenden and Saunders, 1932, p.12).

Ts = The mean temperature of the surroundings) Absolute temperatures on the Farenheit scale.
Tg = The temperature of the globe)

tg = The temperature of the globe) On the Farenheit scale.
ta = The air temperature)

v = The air velocity in feet per minute.

Results

Thermocouple readings		Globe	Silvered
Insulated couple m.v.	Silvered couple m.v.	°F.	°F.
0.870	0.875	83.1	71.8
0.865	0.875	83.2	71.9
0.875	0.870	83.2	71.9
0.875	0.860	83.2	71.8
0.870	0.870	83.2	71.9
0.880	0.870	83.2	71.9
0.870	0.870	83.2	71.9
0.870	0.865	83.2	71.9
0.870	0.860	83.2	71.9
0.880	0.875	83.3	71.9
0.8725 =71.8°F	0.869 =71.7°F	83.2°F	71.9°F Mean

The two thermocouples and the silvered thermometer were immersed in water at a temperature approximately equal to that of the air in the above test and it was found that it was not necessary to apply any correction to the above observed differences.

The difference between the means of the thermocouple readings was 0.0035 with a standard error 0.0024 ($t = 1.48$). Not Significant. Using the above equations $Ts = 89.2°F.$ and $Hr = 6.43$ B.T.U./sq.ft./hr. Therefore with the mean temperature of the surrounds exceeding that of the air by 17.3°F. it was shown that no significant increase in the surface emissivity of the thermocouples was caused as a result of the addition of the thin layer of insulation.

Rate of Aspiration of the Elements. This was measured by means of a hot wire anemometer the element of which was 2 cms. long and 0.2 cms. in width. It had been calibrated over the range 0 to 5 ft./sec. but was not sensitive to changes in air velocity above the upper limit. Since it had been found that at least three elements could be ventilated simultaneously without introducing an error in the wet bulb depression the air velocity past the elements under such conditions was ascertained, using the lengths of rubber tubing which would be used in physical and user test studies.

The hot wire element was introduced into the air stream in the plane of the thermomenter relative to the orifice. Readings were taken with the element on each side of the thermometer in this plane.

Results.

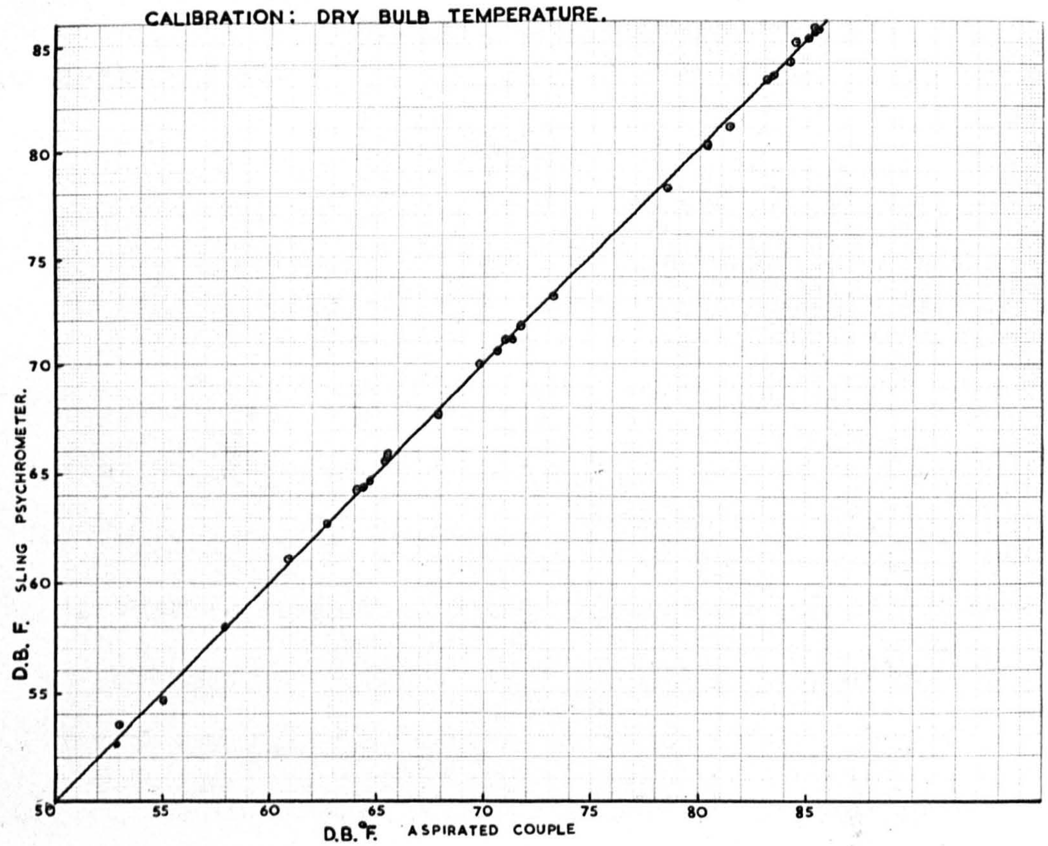
Ten readings were taken on each side of the thermometer which gave a mean value of 174 ft./minute for the velocity of the air stream entering the orifice. Pasquill found that for 28 gauge copper constantan thermocouples the acceptable minimum was 394 ft./sec. and Hilpert[11], using 40 gauge manganin-constantan thermocouples found that an air velocity of 39.4 ft./min. was sufficient to produce a maximum wet bulb depression.

Displacement of Room Air Due to Aspiration. It will be remembered that an essential requirement of apparatus for the rapid assessment of environmental thermal changes in small rooms was that the aspiration did not produce turbulence or a marked displacement of the ambient air. By suspending the Assmann psychrometer outside the experimental room the possibilities of turbulent air motion are eliminated.

The displacement of room air due to the simultaneous aspiration of three elements was measured by means of an accurate Siebe Gorman air flow meter. It was found that in 2 minutes (the time necessary for full aspiration and reading of the potentiometer) 41.60 litres of room air were displaced. The volume of the room in which the apparatus would principally be used was 32017 litres (1130.54 cu.ft.). Using the figure of 1 room air change per hour, being approximately the minimum value with no fire and windows, hoppers and doors closed, it can be seen that the ratio of air displaced by the aspiration during 2 minutes to that by natural ventilation during the same time is

$$\frac{41.6 \times 30}{32017} = \underline{0.039}.$$

If eight sets of readings were to be taken every hour the volume of air displaced in this way would amount to only 1% of the total volume displaced by natural ventilation. This figure is inversely proportional



CALIBRATION: DRY BULB TEMPERATURE.
D.B. F. SLING PSYCHROMETER.
D.B. °F. ASPIRATED COUPLE
50
55
60
65
70
75
80
85

FIG 1.3.

to the air change rate and therefore 1% is the maximal error. Both physically and physiologically it can be considered negligible.

Calibration of the Elements. The method adopted to assess the accuracy of the readings given by the elements used and constructed as described in the previous section, consisted essentially of a careful calibration of one element against a standard method followed by a comparison of the calibrated element with the remaining five made up and used in exactly the same manner.

The initial calibration was carried out in an air conditioned cubicle*. The routine experimental procedure was to compare the readings of the elements with those of a whirling hygrometer used in the conventional way. The Assmann psychrometer, used for aspirating the elements, was placed outside the cubicle to exclude the turbulent air movement it caused from the experimental room. The ranges of temperatures and humidities employed for the calibration adequately covered those which would be encountered in studies of kitchen climate, namely 50°F. to 85°F. dry bulb temperature, 40% to 95% relative humidity (the obtainable maximum).

Between observations the air was constantly stirred by an electric fan which was switched off whilst readings were being taken in order to reduce to a minimum extraneous causes of air movement. A two kilowatt electric heater was also used in the experimental room to similate a source of radiation approximating to that of a coal fire.

*Details of the Air Conditioned Cubicle are given in Chapter 5.

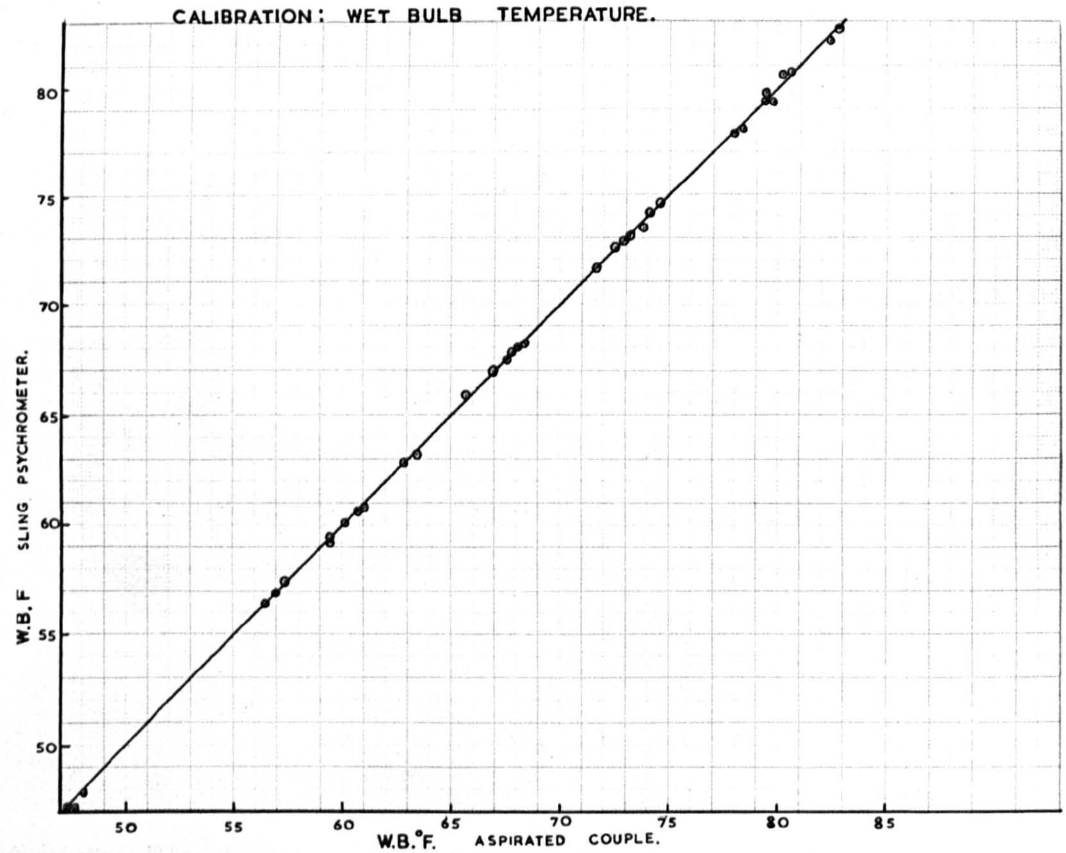

CALIBRATION: WET BULB TEMPERATURE.
W.B. F SLING PSYCHROMETER.
W.B.°F. ASPIRATED COUPLE.
50
55
60
65
70
75
80
85

FIG 2.10

Readings of the thermoelectric e.m.f's were followed, for each comparison, immediately by readings of the wet and dry bulb temperatures of the whirling hygrometer used conventionally, and pairs of readings were repeated until steady values were obtained. This procedure was repeated at 35 different wet bulb and 29 different dry bulb temperatures which covered the complete range of temperatures and humidities stated above. The thermometers of the whirling hygrometer were calibrated against the thermocouples by immersion in water over the range of temperatures above. Before the calibration curves for the two instruments were plotted, the thermometer readings were corrected accordingly.

Figures 1.3 and 1.4 are calibration curves for the dry bulb and wet bulb temperatures respectively. It will be seen that there are no systematic errors. Deviations from the line could be accounted for by experimental errors.

Further comparison of this instrument with five others, which was checked from time to time during experimental use, was carried out in one of the rooms at the Field Test Unit. Each instrument was checked separately against the pre-calibrated one at about six points over the range of temperature and humidity specified above. All the instruments checked in this way showed no systematic errors.

Thus a method for the rapid assessment of changes in air temperatures and humidity, comparable in accuracy to that of an instrument which has been widely used in thermal environmental studies was available. It was a method which would not interfere with the routine performance of specific domestic tasks by working subjects.

Use of Thermometers for the Measurement of W.B. Temperature.

The recommended rate of aspiration for the wet bulb of a whirling hygrometer is 600 ft. per minute(12), i.e. 3.05 metres per second. Therefore for the reduced rate of aspiration of 174 ft. per minute (0.88 metres/sec.) a correction must be applied to obtain a correct value for the wet bulb depression.

An approximate correction can be applied as follows:-

The fundamental psychrometric formula is:

$$m_2 \left(\frac{pw - p}{P}\right) = m_1 \frac{Sp}{Lr} (t - tw)$$

where pw & p are the saturation and actual vapour pressures at tw

P = Barometric pressure

L = Latent heat of water at tw

r = Specific gravity of aqueous vapour compared with air

Sp = Specific heat of air at constant pressure

m_1 = Mass of air which is cooled from t to tw in unit time

m_2 = mass of air saturated in unit time at temperature tw

The formula is generally written:

$$\frac{pw - p}{P} = A\,(t - tw), \text{ where } A = \frac{Sp}{Lr} \cdot \frac{m_1}{m_2}$$

At high velocities it is evident that $m_1 = m_2$ (13) and the formulae

$$\frac{pw - p}{P} = A\,(t - tw), \text{ where } A = 0.00064 \text{ can be used.}$$

If one neglects the radiation effect for velocities below that at which $m_1 = m_2$ the temperature of the wet bulb falls until the diffusion of heat to the bulb from the warmer incident air balances the heat loss by evaporation due to the diffusion of water vapour from the bulb into the air stream. Dimensional analysis[13] of this transfer of heat gives:

$$\frac{pw - p}{P} = \frac{Sp}{Lr}\,(t - tw)\ f\left(\frac{vl}{k}\right)$$

v = velocity of air stream

l = a linear dimension of the bulb

k = Kinematic viscosity.

For velocities less than 3.05 metres per second therefore the wet bulb depression depends upon the velocity of the air stream and the dimensions of the wet element. Above this velocity $f(\frac{vl}{k})$ is constant.

F.S. Skinner[14] has investigated the variation of wet bulb depression with rate of aspiration. Although the size of the thermometer bulb used was not disclosed the variation of $f(\frac{vl}{k})$ between 3 and 4 metres per second was only 5%. These results showed

$$\frac{f(\frac{vl}{k})\ \ v = 3\ \text{metres/sec.}}{f(\frac{vl}{k})\ \ v = .88\ \text{metres/sec.}} = \frac{.62}{.5}$$

Therefore to correct for the reduced air speed the psychrometer formula should be

$$\frac{pw - p}{P} = \frac{0.00064 \times .62}{.5}\,(t - tw)$$

$$\text{i.e.}\ \ \frac{pw - p}{P} = .00079\,(t - tw)$$

This is very close to the value of 0.0008 advocated for use with instruments exposed to "light winds" (Kaye & Laby. Physical & Chemical Constants, p. 40). Although this is rather a vague definition it does suggest that the error in using the figure 0.00079 for correcting the wet bulb depression would be small.

Therefore the true fully aspirated wet bulb temperature, assuming zero error for the dry bulb reading can be obtained from:

$$(T_1 - T_2) \times 0.00064 = (T_1 - t_2) \times 0.00079$$

where T_1 = observed D.B. temperature

t_2 = " W.B. "

T_2 = True W.B. "

__Summary__

1. The construction of apparatus for the rapid measurement of changes of temperature and humidity at several points in a room has been described.

2. Bearing in mind that these measurements would be taken whilst domestic operations were in progress a remote reading method was employed.

3. 32 gauge copper-constantan thermocouples were attached to the wet and dry bulb elements of suspended whirling hygrometers and the aspiration of the couples was achieved through lengths of rubber tubing by the fan of an Assmann psychrometer.

4. The apparatus was calibrated against a whirling hygrometer used in the conventional manner.

5. The calibration showed no systematic errors; The accuracy therefore appeared to be comparable with that of an instrument which has been widely used in environmental thermal studies.

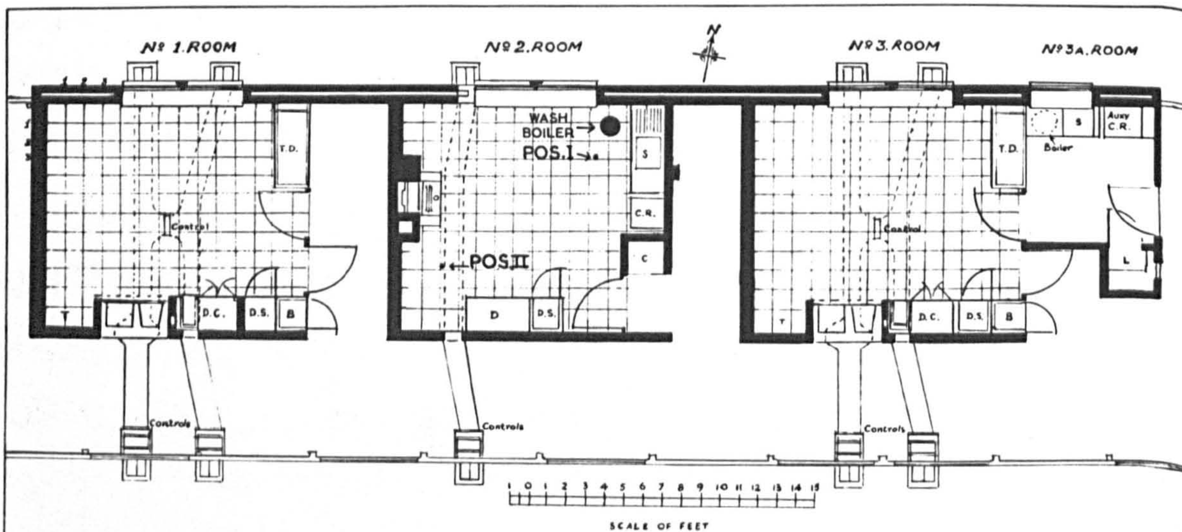
CHAPTER II

The Effect of Different Ventilating Methods on Temperature and Humidity Distribution and Control during the Operation of a Gas Wash Boiler.

It is well known that marked changes in room climate occur in kitchens or kitchen living rooms as a result of the housewife performing a weekly family wash. These changes in temperature and humidity can be considerable when use is made of a domestic gas wash boiler which is one of the most common appliances in use at the present time.

These marked environmental changes in temperature and humidity in the kitchen occur while the housewife is exerting a good deal of muscular effort which increases her body heat production. Hence it is important that these climatic changes should be as small as possible in order to increase the comfort and efficiency of the housewife and, at the same time, reduce the fatigue resulting from this particular domestic task.

The purpose therefore of this series of experiments, being a purely physical study, was to examine the effect of different ventilation rates and methods upon the distribution of temperature and humidity when a standard gas wash boiler was alight for a period of 75 minutes. This period of time was chosen as the rate and duration of gas consumption corresponded approximately with user practice.



PLAN OF EXPERIMENTAL KITCHEN LIVING ROOMS

POSITION REFERENCE

FLOORS ARE MARKED OUT IN 1 FT. SQUARES NUMBERED AS INDICATED IN ROOM Nº 1

KEY TO FITTINGS			
B.	BROOM CUPBOARD		
C.	CUPBOARD		
D.C.	DRYING CUPS	T.	TABLE
D.S.	DRY STORES	C.R.	COOKER
T.D.	THROUGH DRESSER	S.	SINK
D.	DRESSER	L.	LARDER

FIG. 2.1

Experimental Methods

I. These studies were conducted entirely in one of the experimental rooms at the Thatched Barn Field Test Unit, Boreham Wood, Herts. Three full size kitchen living rooms, 14 ft. x 12 ft. x 8 ft. as specified in approved designs were constructed inside a standard Ministry of Works hut. A complete plan of these rooms is shown in Fig. 2.1. These rooms were made available to the department under the Extra-Mural Research Contract with the Ministry of Works. They were an essential requirement for a scientific investigation of thermal comfort in relation to the heating and ventilation of dwellings, and the effect of weather conditions, which comprised the whole research programme of which the experiments described in this thesis formed an integral part. No. 2 Room, being a kitchen living room of the modern convertible flat type afforded the best opportunity of studying this particular problem.

The gas wash boiler was located near the sink (see Fig. 2.2 & 2.3). The build up and decay of temperature and humidity resulting from the gas wash boiler being lit from t = 30 to t = 105 mins was measured at 6 points in the room at 15 minute intervals from t = o to t = 195 mins and then half hourly until the final reading at t = 255 mins. The six points were:-

(a)	Stand I In the "working space"	(b)	Stand II The remote corner
POS I_1	6' 6" level	POS II_1	6' 6" level
POS I_2	4' 0" level	POS II_2	4' 0" level
POS I_3	6" level	POS II_3	6" level

(see fig. 2.1)

POSITION OF FAN AND WINDOWS RELATIVE TO THE WORKING SPACE.

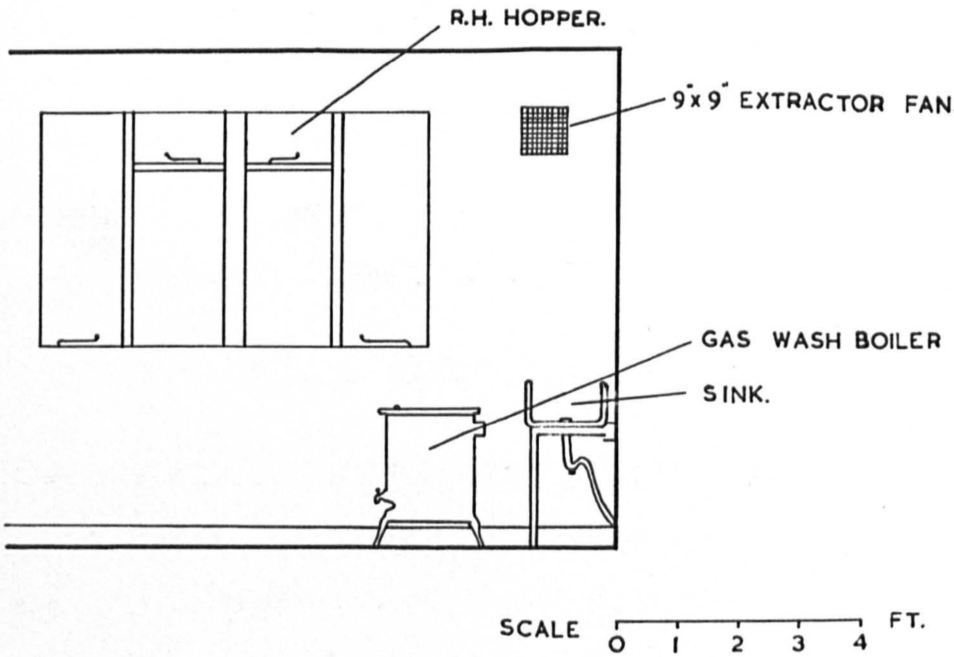


FIG. 2.2

32 gauge copper/constantan thermocouples were attached to the wet and dry bulbs of suspended whirling hygrometers thus providing a remote reading method for wet bulb and dry bulb temperatures. Aspiration of 3 instruments simultaneously was achieved by lengths of rubber tubing linked to the fan of an external Assmann psychrometer in the manner described in the previous chapter.

The ventilation arrangements involved two levels (presence and absence) of 3 factors namely:-

1. Coal fire, refuelled at a standard rate of 3/4lb. every ¼hr. All air ducts and registers closed.

2. The right hand hopper window.

3. A 9" x 9" fixed grill A.C. extractor fan, 1320 r.p.m., air delivery 300 cu. ft./min. located as shown in fig. 2.2. The 8 treatment combinations consisted of all combinations of

Coal Fire	Right Hopper Window	Extractor fan
(F)	(h)	(f)
Not lit	Opened	Off
Lit.	Closed	On.

There were 4 replications of each treatment combination making 32 experiments in all, designed as a simple factorial experiment to eliminate as far as possible any variation between days. For the purpose of comparing the main effects and interactions of these

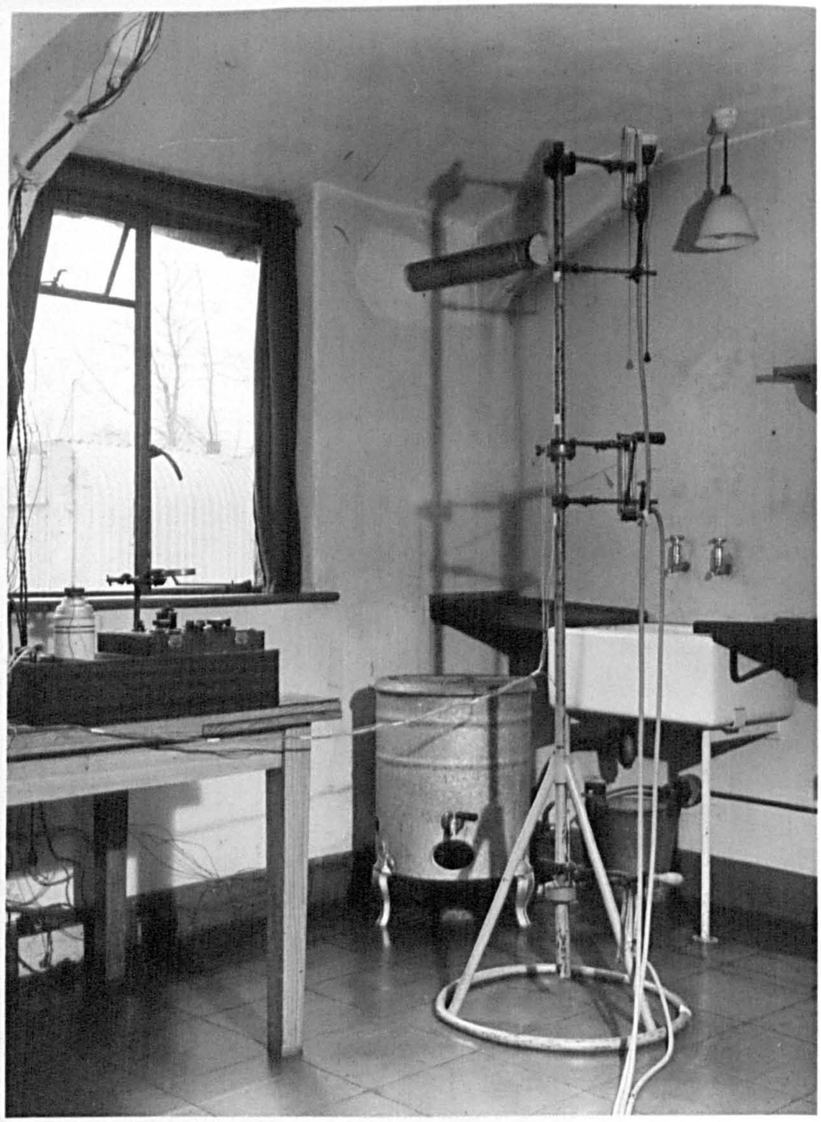


FIG. 2.3

Position of gas wash boiler relative to the sink, hopper and casement windows and Position I.

factors I have taken as the variables or treatment figures

$$\sum_{t=o}^{t=255} (T - To), \quad \sum_{t=o}^{t=255} (T^1 - T^1o) \text{ and } \sum_{t=o}^{t=255} (H - Ho) \text{ where}$$

T, T^1 & H = D.B. & W.B. temperatures and relative humidity respectively at any particular time.

To, T^1o & Ho = D.B. & W.B. temperatures and relative humidity at $t = o$.

The temperatures and humidities at the 4 ft. levels (POS I_2 & II_2) will have the most important bearing on the physiological and subjective reactions in later studies. Therefore it was decided not to introduce positions as another variable in the analysis but to treat each one separately with particular emphasis on these two important positions.

The volume of gas combusted and the quantity of water evaporated from the wash boiler were measured on each occasion, together with a record of the external weather conditions.

Finally, experiments were carried out to determine the number of room air changes per hour for the four treatments which did not include the exhaust fan. The purpose of these experiments was to ascertain if a relationship could be established between the build up and decay of relative humidity and the over-all air change rate for the room.

Results

A. Mid Level. Working Space. Position I_2.

1. Dry Bulb Temperature.

Treatment (1) was that in which all three factors were absent, i.e. Control Treatment.

Table 2.1.

Treatment	Repetitions (1)	(2)	(3)	(4)	Treatment. Totals.	Treatment Means.
1	124.5	134.4	156.0	158.5	573.4	143.35
h	123.0	110.6	121.2	130.4	485.2	121.3
F	152.6	167.5	146.8	148.6	615.5	153.87
Fh	118.7	93.4	132.5	108.0	452.6	113.15
f	77.6	44.7	79.9	87.9	290.1	72.52
fh	69.7	57.2	44.8	67.7	239.4	59.85
Ff	176.4	209.3	201.2*	222.5*	809.4	202.35
Ffh	99.0	149.1	101.9	123.9	473.9	118.47
BLOCK TOTALS	941.5	966.2	984.3	1047.5	3939.5	GRAND TOTAL

Each figure in columns (1), (2), (3) and (4) is $\sum_{t = o}^{t = 255} (T - To)$ which can physically be interpreted as (n - 1) times the mean excess temperature above the initial temperature to, where n is the number of observations carried out during each experiment. In this case n = 16.

*The series of experiments Ff (Fan and fire) were abandoned after two tests which showed this combination to be undesirable for reasons which are given below.

There was a decrease in atmospheric pressure in the room due to the extraction of approximately 300 cu. ft. of air per minute by the fan in addition to that extracted initially by the pull of the coal fire. This displaced air could not be replaced by leakage through cracks round the window casings and door edges. The result was that some replacement of the air exhausted by the fan was effected by air flow down the flue against the pull of the fire. This caused the early development of a smoky haze in the room which would make conditions impossible for clothes washing. Subsequent experiments have shown that such a condition is not fully remedied by the inclusion of an 8" x 5" air brick at the lowest level vertically below the fan grill.

Therefore, there were no experimental treatment figures for Ff under columns (3) and (4). These values were estimated as described in Appendix 2 B.

Table 2.2

Analysis of Variance (see footnote)

	D.F.	Sum of Squares.	Mean Square	Variance	
Blocks	3	769.04	256.34	0.873	
Treatments M	1	12692.22	12692.22	43.24**	(-)
F	1	18207.09	10207.09	62.04**	(+)
Fh	1	4038.75	4038.75	13.76*	(-)
f	1	3079.16	3079.16	10.49*	(-)
fh	1	570.37	570.37	1.94	(-)
Ff	1	17311.95	17311.95	58.99**	(+)
Ffh	1	1379.43	1379.43	4.70+	(-)
ERROR	19	5576.44	293.49		
TOTAL	29	63624.45			

See Appendix 2.A. for statistical method employed.

The two estimated values cause a reduction in the error degrees of freedom from 21 to 19.

** Significant at 0.1%

* Significant at 1.0%

+ Significant at 5.0%

S.D. of the difference between two treatment means =

$$(293.49\ (\tfrac{1}{4} + \tfrac{1}{4}))^{\frac{1}{2}} = \underline{12.11}$$

The three main effects all appear to be significant, the hopper and the fan in causing a reduction in dry bulb temperature increases, whilst the fire, as expected produced a significant increase. The three interactions involving the fire were significant, Fh and Ffh producing a reduction and, again as expected, Ff an increase above the increases resulting from the control treatment (1). Table 2.3 shows the mean values of the average increases in the dry bulb temperatures for all the treatments. They are derived from the figures in the final column of Table 2.1 divided by 15.

Table 2.3

Mean D.B. temperature Increases throughout the experimental period.

Treatment	Fire not lit	Fire lit
1	9.55	10.26
h	8.09	7.54
f	4.83	13.49
fh	3.99	7.90

$$\text{S.D. of the difference} = \frac{12.11}{15} = 0.807$$

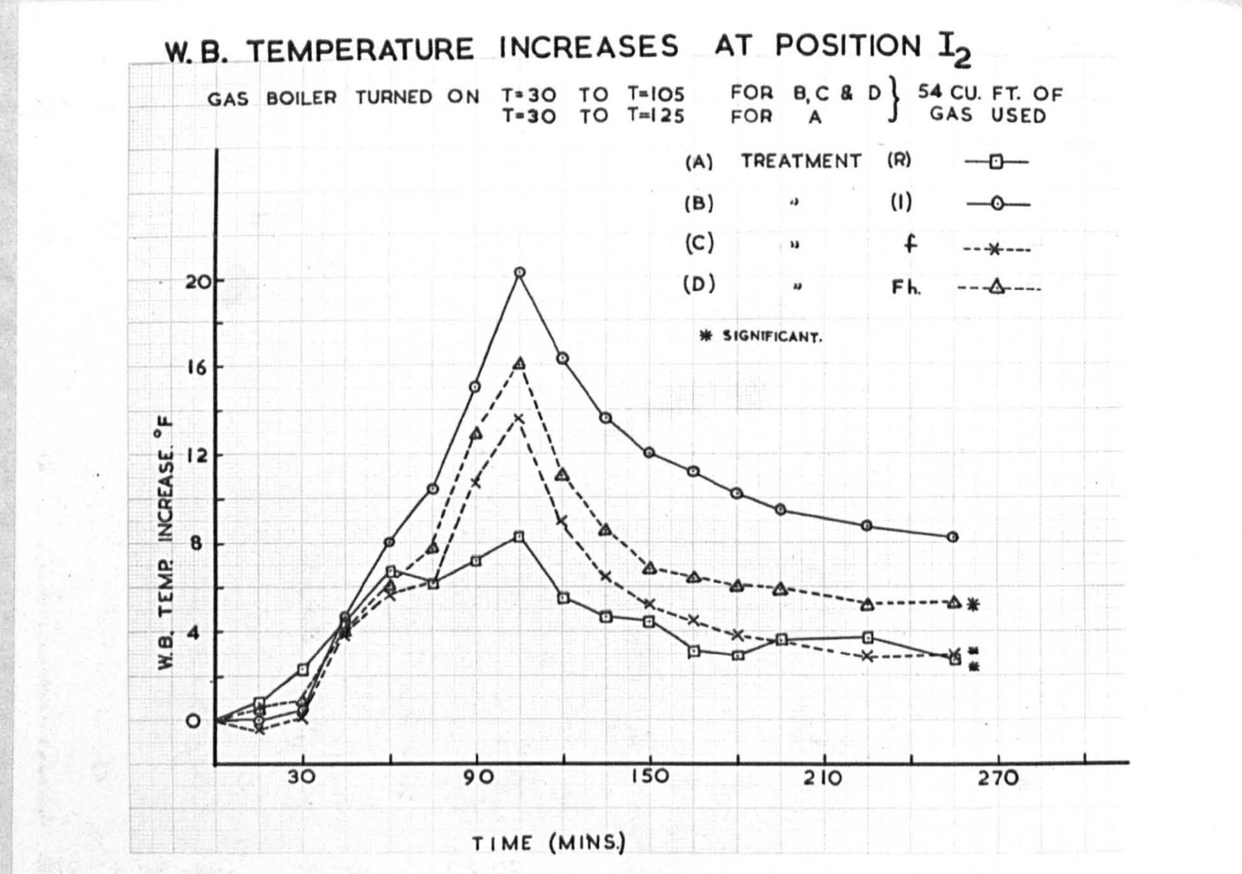

W. B. TEMPERATURE INCREASES AT POSITION I2
GAS BOILER TURNED ON T=30 TO T=105 FOR B, C & D
T=30 TO T=125 FOR A
54 CU. FT. OF GAS USED
(A) TREATMENT (R)
(B) " (I)
(C) " f
(D) " Fh.
* SIGNIFICANT.
W.B. TEMP. INCREASE. °F
0
4
8
12
16
20
30
90
150
210
270
TIME (MINS.)

FIG 2.a.i.

The fan was obviously the most effective single factor. However, a result of particular interest is that a significant reduction was produced by Fh (treatment mean 7.54°F) by virtue of the significant interaction between these two factors. Further, when the fire was lit the hopper was the most important factor in the reduction of the build up of dry bulb air temperature at the 4 ft. level in the working space.

2. Wet Bulb Temperature.

Table 2.4

Treatments	Repetitions 1	2	3	4	Treatment Totals	Treatment means
(1)	136.1	143.4	165.8	150.4	595.7	148.9
h	131.4	131.3	112.8	131.7	507.3	126.8
F	148.6	148.4	168.8	149.4	615.2	153.8
f	85.5	54.4	70.9	94.4	305.2	76.3
hF	94.2	131.6	70.1	108.9	404.8	101.2
hf	63.5	70.6	32.8	71.5	238.4	59.6
Ff	140.5	159.9	147.4*	154.8*	6026	150.6
Ffh	81.4	93.2	117.6	88.1	380.3	95.1
BLOCK TOTALS	881.2	932.8	886.3	949.2	3649.5 GRAND TOTAL.	

Table 2.5

Analysis of Variance

		Degrees of Freedom	Sums of Squares	Mean Square	
Blocks		3	416.26	138.75	
Treatments	h	1	10800.82	10800.82*	(-)
	F	1	3967.17	3967.17**	(+)
	Fh	1	2406.44	2406.44**	(-)
	f	1	11119.44	11119.44*	(-)
	fh	1	2.94	2.94	(-)
	Ff	1	8524.91	8524.91*	(+)
	Ffh	1	35.04	35.04	(-)
ERROR		19	5504.54	289.71	
TOTAL		29	42777.56		

** Significant at 1% level
* Significant at 0.1% level.

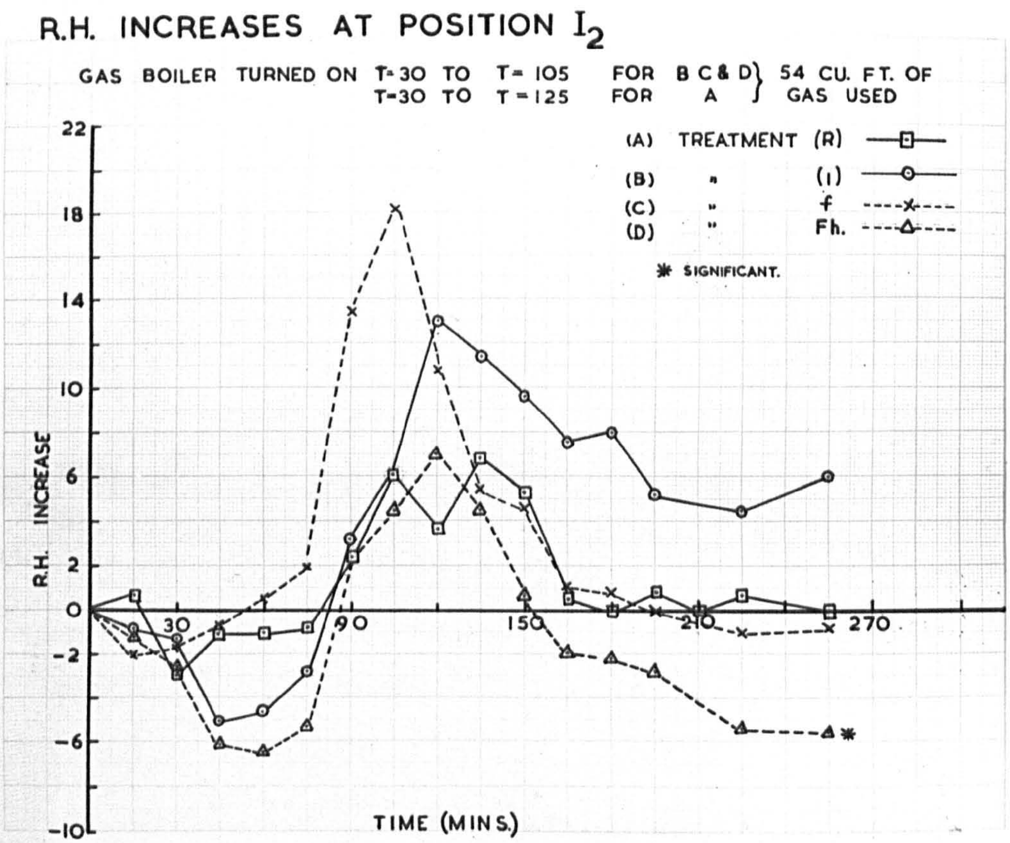

R.H. INCREASES AT POSITION I2
GAS BOILER TURNED ON T=30 TO T=105 FOR B C & D } 54 CU. FT. OF GAS USED
T=30 TO T=125 FOR A
(A) TREATMENT (R)
(B) " (I)
(C) " f
(D) " Fh.
* SIGNIFICANT.
R.H. INCREASE
TIME (MINS.)
22
18
14
10
6
2
0
-2
-6
-10
30
90
150
210
270

FIG. 2.5.

The standard deviation of the difference between 2 treatment means

$$= (289.71\ (\tfrac{1}{8} + \tfrac{1}{8}))^{\frac{1}{2}} = \underline{11.94}$$

The 3 main effects all appear to be significant. Factors f and h produced significant reductions in the W.B. temperature increases whilst factor F as expected produced a significant increase above the increases resulting from the ventilation derived from the absence of all factors. However, since 2 of the interactions, F with h and F with f were also significant the data had to be examined in more detail. Subdividing the treatments into two groups, all those treatments with F being separated from the remainder we obtain the following table. From this table we see that in the absence of the Fire (F) the fan (f) produced the most significant effect. Its effect however was lost when the fire was lit. The difference between f and fh treatment means was not significant.

Table 2.6

Mean Increases in Wet Bulb Temperature.

	Fire not lit	Fire lit
1	9.92	10.26
h	8.46	6.74
f	5.08	10.04
fh	3.97	6.34

Standard deviation of the difference $= \dfrac{11.94}{15} = 0.79^{\circ}F$

However, when the fire was on the hopper appeared the most important single factor in reducing the build up of temperature. Furthermore the interaction of F with h was significant. The hopper had a slight but barely significant effect when the fire was not lit.

3. Relative Humidity

Table 2.7

Treatments	Repetitions 1	2	3	4	Treatment Totals.	Treatment Means.
(1)	72	84	97	77	330	82.5
h	94	12	100	23	229	57.2
F	7	54	35	46	142	35.5
f	74	73	0	56	203	50.7
Fh	-100	-94	79	33	-82	-20.5
fh	3	97	-41	45	104	26.0
Ff	-94	-45	-63*	-88*	-290	-72.5
Ffh	109	-37	2	-77	-3	-0.75
BLOCK TOTALS	165	144	209	115	633 GRAND TOTAL	

* Estimated Values.

Table 2.8

Analysis of Variance.

		Degrees of Freedom	Sum of Squares.	Mean Square.	
Blocks		3	593.10	197.70	
Treatments	h	1	586.53	586.53	(-)
	F	1	37743.78	37743.78**	(-)
	Fh	1	2161.53	2161.53	(+)
	f	1	11438.28	11438.28	(-)
	fh	1	8224.03	8224.03	(+)
	Ff	1	318.78	318.78	(-)
	Ffh	1	8096.28	8096.28	(+)
ERROR		19	66697.15	3510.37	
TOTAL		29	135859.46		

** Significant at 1.0%

Standard deviation of the difference between 2 treatment means

$$= (3510.37\,(\tfrac{1}{4}+\tfrac{1}{4}))^{\frac{1}{2}} = \underline{41.89}$$

Table 2.9

Mean Increases in Relative Humidity.

	Fire not lit.	Fire lit
1	5.5	2.4
h	3.8	-1.5
f	3.6	-4.8
fh	1.7	-0.05

Standard deviation of a difference = $\frac{41.89}{15}$ = 2.8

It is seen from table 2.9 that the coal fire was the most effective single factor in the control of the relative humidity increases, treatments Ff and Fh producing significant reductions. Therefore a decrease of practical significance was produced when the fire and the hopper were used to ventilate the room.

The standard deviation of the difference between 2 means, one of which is for treatment Ff is

$$(3510.37\,(1/3 + \tfrac{1}{2}))^{\frac{1}{2}} = 54.08$$

because of the two estimated values.

The effective number for (1) is $1 + 1 + \frac{1}{2} + \frac{1}{2} = 3$

The effective number for Ff is $1 + 1 + 0 + 0 = 2$

Therefore the square root of the mean error Sum of Squares must be multiplied by the factor $(1/3 + \frac{1}{2})^{\frac{1}{2}}$ instead of $(\frac{1}{2} + \frac{1}{2})^{\frac{1}{2}}$ to obtain the standard error.

B. Mid Level. Remote Corner. Position II2

1. Dry Bulb Temperature.

Table 2.10

Treatment	Repetitions (1)	(2)	(3)	(4)	Treatment Totals.	Treatment Means
1	119.5	119.0	144.1	147.1	529.7	132.42
h	115.6	99.7	113.4	117.7	446.4	111.60
F	165.4	179.4	139.6	144.9	629.3	157.32
Fh	123.9	103.0	115.8	114.2	456.9	114.22
f	66.2	48.4	70.4	81.8	266.8	66.70
fh	64.9	56.5	43.2	62.2	226.8	56.70
Ff	163.7	182.7	174.5*	178.4*	699.3	174.82
Ffh	83.1	135.2	128.0	113.9	460.2	115.05
BLOCK TOTALS	902.3	923.9	929.0	960.2	3715.4	GRAND TOTAL

* Estimated values.

Table 2.11

Analysis of Variance

		D.F.	Sum of Squares.	Mean Square	Variance	
Blocks		3	214.03	71.34		
Treatments	h	1	8937.84	8937.84	37.10**	(-)
	F	1	18818.00	18818.00	78.11**	(+)
	Fh	1	2595.60	2595.60	10.77*	(-)
	f	1	5232.64	5232.64	21.72**	(-)
	fh	1	17.11	17.11	.07	(-)
	Ff	1	9653.55	9653.55	40.07**	(+)
	Ffh	1	378.12	378.12	1.57	(-)
ERROR		19	4577.29	240.91		
TOTAL		29	50424.18			

** Significant at 0.1%
* Significant at 1.0%

S.D. of the difference between 2 treatments means = 10.97. As for Position I2 the three main effects were significant, the fan and hopper causing a reduction and the fire an increase. Also the

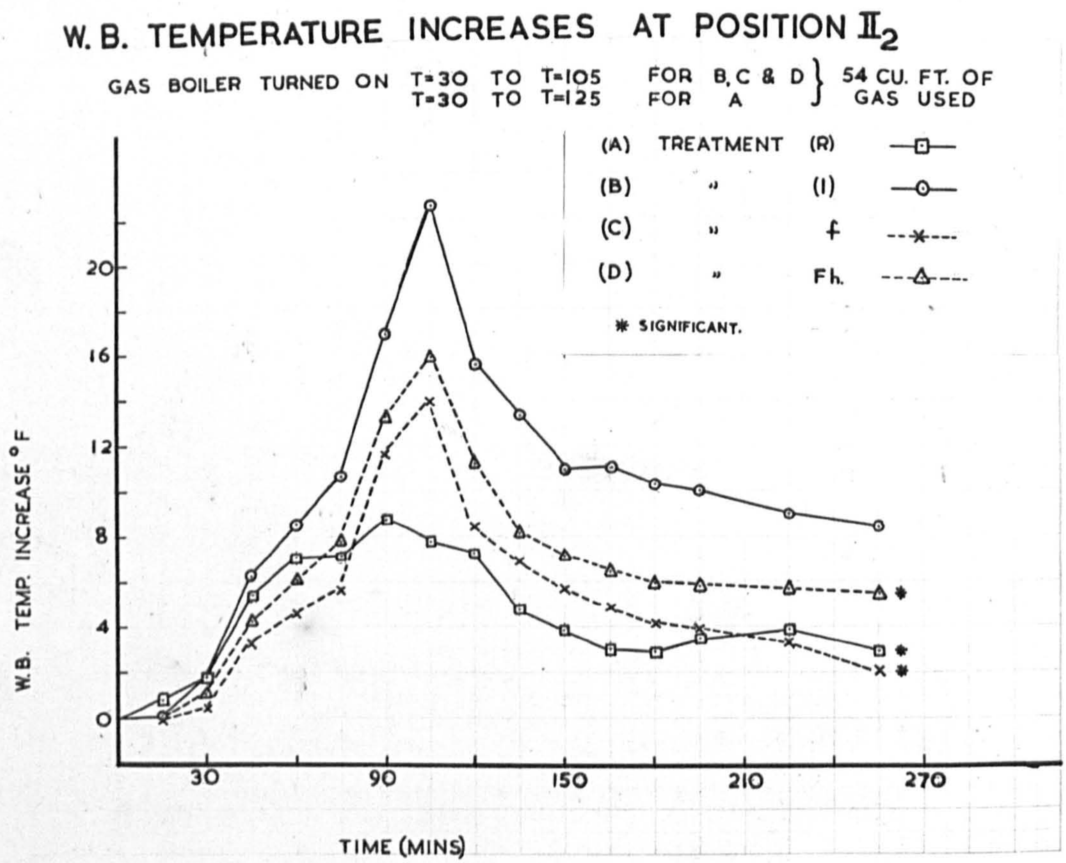

W. B. TEMPERATURE INCREASES AT POSITION II2
GAS BOILER TURNED ON T=30 TO T=105 FOR B, C & D
T=30 TO T=125 FOR A
54 CU. FT. OF GAS USED
(A) TREATMENT (R)
(B) " (I)
(C) " f
(D) " Fh.
* SIGNIFICANT.
W.B. TEMP. INCREASE °F
0
4
8
12
16
20
30
90
150
210
270
TIME (MINS)

FIG. 2.6.

interactions of (F) with (h) and (F) with (f) appeared significant. The mean increases in temperature derived from table 2.10 are shown below.

Table 2.12

Mean Increases in Bulb Temperature

	Fire Off	Fire On.
(1)	8.83	10.49
(h)	7.73	7.61
(f)	4.45	11.65
(fh)	3.78	7.67

Standard deviation of a difference = $\frac{10.97}{15}$ = 0.73

Here again, the fan was the most important single factor. The analysis of variance table shows interaction Fh to be significant. The difference between the treatment means for Fh and (1) (1.22°F) is slightly less than the value required for significance (0.73 x 2.09 = 1.52°F). Therefore, the significance of the reduction of the dry bulb temperature due to the treatment Fh when compared with the control treatment is doubtful. At this position the convected heat from the fire has more effect than at the working space. However, the difference between the treatment means for F and Fh (2.87°F) is clearly significant.

2. Wet Bulb Temperature

Table 2.13

Treatments	Repetitions 1	2	3	4	Treatment Totals.	Treatment means
(1)	151.6	167.2	143.8	160.7	623.3	155.8
h	123.4	132.3	113.2	124.7	493.6	123.4
f	68.0	85.4	63.1	97.7	314.2	78.55
F	167.0	149.1	180.4	149.3	645.8	161.45
Fh	99.6	111.2	92.1	108.8	411.7	102.9
Ffh	60.8	105.5	86.2	72.2	324.7	81.2
fh	68.0	21.9	61.5	65.0	216.4	54.1
Ff	123.1	137.0	127.7*	132.8*	520.6	130.15
BLOCK TOTALS	861.5	909.6	868.0	911.2	3550.3	GRAND TOTAL

* Estimated values.

Table 2.14

Analysis of Variance

		Degrees of Freedom	Sum of Squares.	Mean Square
Blocks		3	263.29	87.76
Treatments	h	1	13509.57	13509.57* (-)
	F	1	2036.81	2036.81**(+)
	Fh	1	1281.44	1281.44+ (-)
	f	1	19925.07	19925.07* (-)
	fh	1	153.56	153.56 (+)
	Ff	1	4373.46	4373.46* (+)
	Ffh	1	1.24	1.24 (+)
ERROR		19	4548.12	239.37
		29	46092.56	

\+ Sign at 5%
** Sign at 1.0%
* Sign at 0.1%

S.D. of difference between 2 means = $\left(239.37\left(\frac{1}{4}+\frac{1}{4}\right)\right)^{\frac{1}{2}}$ = **10.94**

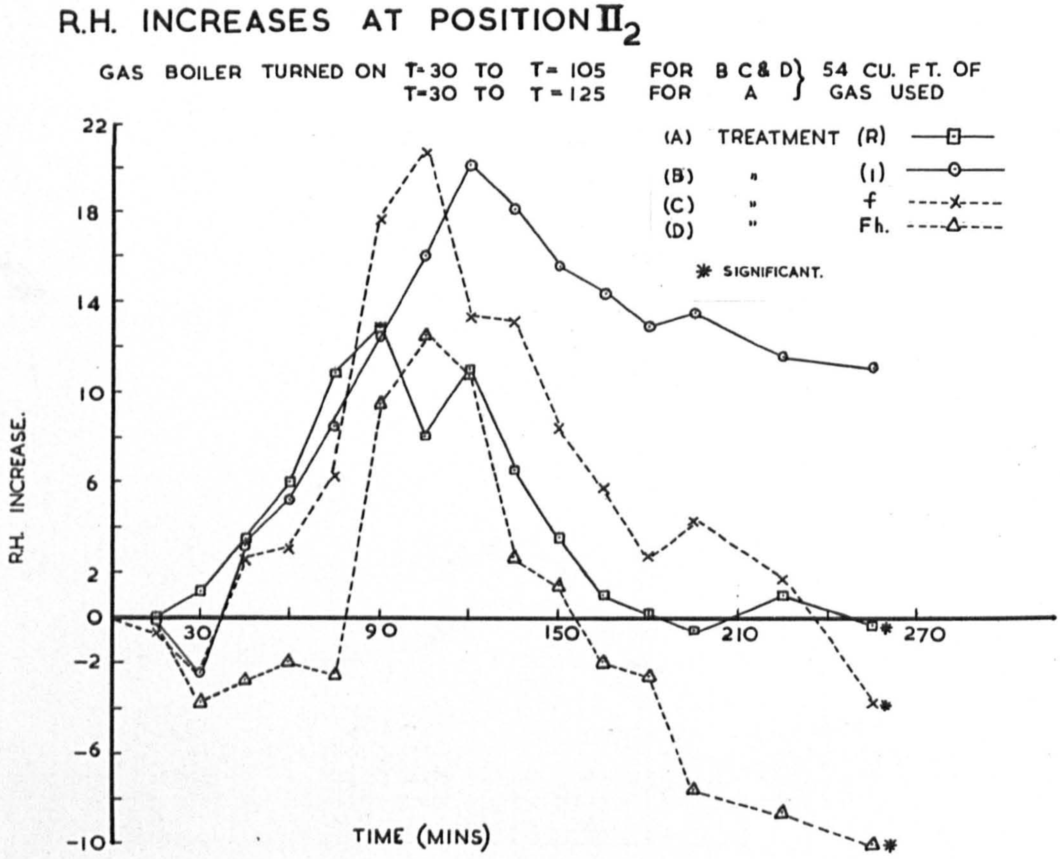
Table 2.15

Mean Increases in Wet Bulb Temperature.

	Fire not lit	Fire lit
1	10.39	10.76
h	8.23	6.86
f	5.24	8.68
fh	3.60	5.41

Standard deviation of a difference = $\frac{10.94}{15}$ = 0.73

The analysis showed that the fire alone produced an increase in W.B. temperature above that of the control treatment (1). That was to be expected. Its effect was to cause a significant increase at the 5% level. It is clear from the analysis and the above table that the extractor fan was the most important single factor. The hopper window also gave rise to a significant reduction. The general effect of F appears to be to increase the W.B. temperature increases when comparing the right and left hand columns of the above table except when comparing treatments Fh and h. There is a reverse difference which the t test proves to be significant at the 0.1% level. Treatment Fh produced a significant effect and the interaction of F with h was significant at the 5% level from the analysis of variance table.



R.H. INCREASES AT POSITION II2
GAS BOILER TURNED ON T=30 TO T=105 FOR B C & D } 54 CU. FT. OF
T=30 TO T=125 FOR A } GAS USED
(A) TREATMENT (R)
(B) " (I)
(C) " f
(D) " Fh.
* SIGNIFICANT.
22
18
14
10
6
2
0
-2
-6
-10
30
90
150
210
270
R.H. INCREASE.
TIME (MINS)

FIG. 2.7.

3. Relative humidity

Table 2.16

	Treatment Figures 1	2	3	4	Treatment Totals.	Treatment means
1	195	129	197	110	631	+158.0
h	85	104	160	85	434	+108.5
f	31	107	95	136	369	+ 92.25
F	73	91	122	88	374	+ 93.5
Fh	-104	2	35	49	-18	- 4.5
fh	63	45	-74	40	74	+ 18.5
Ff	-121	-24	-52*	-59*	-256	- 64.0
Ffh	-62	-113	-65	-92	-332	- 83.0
BLOCK TOTALS	160	341	418	357	1276	GRAND TOTAL

* Estimated values.

Table 2.17

Analysis of Variance

		Degrees of Freedom	Sum of Squares.	Mean Square
Blocks		3	4626.25	1532.08
Treatments	h	1	28800.00	28800.00** (-)
	F	1	94612.50	94612.50* (-)
	Fh	1	18.00	18.00 (+)
	f	1	76636.12	76636.12* (-)
	fh	1	1485.12	1485.12 (-)
	Ff	1	3240.12	3240.12 (-)
	Ffh	1	5356.12	5356.12 (+)
		19	45175.25	2377.64
		29	259949.48	

* Sign. at 0.1%
** Sign. at 1.0%

S.D. of difference between 2 means = $(2377.64\ (\frac{1}{4}+\frac{1}{4}))^{\frac{1}{2}}$ = 34.4

Table 2.18

Mean Increases in Relative Humidity

	Fire Off	Fire On
1	10.5	6.2
h	7.2	-0.3
f	6.1	-4.3
fh	1.2	-5.5

Standard deviation of a difference = $\frac{34.4}{15}$ = 2.29

The analysis of variance showed all three main effects to be significant. The maximum reductions in relative humidity increases were produced by treatments Ffh, Ff, Fh and fh in that order.

Figures 2.4, 2.5, 2.6 and 2.7 illustrate the build up and decay of temperature and humidity with time for the treatments (1) (R) (f) and (Fh) for the two positions discussed. Each point on the graph is the mean of the four observations of the factorial experiments and the four experiments with (R).* Significant treatments are indicated in each case.

The 6' 6" and 6" levels (Positions I_1, I_3, II_1 and II_3).

As previously explained the mid level positions have been given a full and careful analysis because the temperatures and humidities at these two positions will have the most important bearing on the physiological and subjective reactions in later experiments. However, some consideration must be given to the effects produced at the remaining 4 positions.

* see page 47

Using the data from the factorial experiment there were 4 replications of 8 treatment values at 4 different positions. The data had therefore three criteria of classification. In this case I took as the variables or treatments figures:-

(T max - To), (T^1 max - To^1) and (H max - Ho) where T max, T^1max and H max are the maximum values of dry bulb, wet bulb temperatures and relative humidity obtained at the respective positions.

Therefore, whereas for positions I_g and II_g I was concerned with the general level of the temperatures and humidities because of their physiological significance, for the remaining positions I have considered merely the effects of the different ventilating methods on the maximum increases of temperature and humidity. These values were measured immediately before the gas wash boiler was turned off.

Table 2.19

Results

(a) Maximum D.R. Temperature Increases

TREATMENTS	POSITIONS															
	I_1				I_3				II_1				II_3			
1	21.0	20.7	24.4	24.5	8.2	9.2	8.5	8.7	22.0	21.0	24.8	24.3	5.6	5.6	6.0	5.8
h	22.2	21.8	21.4	21.2	10.1	10.7	9.7	9.7	21.6	20.9	21.8	21.9	7.0	6.6	7.1	7.4
f	13.8	13.1	15.2	14.7	4.3	2.7	4.5	4.4	12.6	12.1	15.5	14.3	2.7	1.2	2.5	3.6
F	20.8	21.1	18.4	19.4	10.9	12.0	10.4	11.5	20.9	21.6	18.5	19.8	6.6	7.5	6.9	6.9
Fh	15.9	18.4	21.4	18.0	11.8	12.7	13.0	12.2	16.6	16.1	19.8	17.1	8.0	8.0	9.3	8.6
fh	10.6	8.4	8.2	12.6	6.7	7.7	6.5	7.0	10.4	8.6	7.0	11.2	4.3	5.2	2.8	4.4
Ff	19.3	23.1	21.7*	22.1*	12.6	12.9	12.4*	12.6*	18.5	20.9	20.3*	20.7*	12.2	13.2	12.6*	13.2*
Ffh	13.0	14.9	12.9	13.6	10.4	13.5	9.9	10.9	10.1	12.0	10.5	11.6	6.7	11.0	8.0	10.0

* 8 values had to be estimated for treatment Ff. Each position was treated separately and the values were arrived at by the method of successive approximations as described in Appendix 2.B. The error degrees of freedom are consequently reduced from 96 to 88.

Table 2.20

Analysis of Variance

Source of Variation	D.F.	Sum of Squares.	Mean Square	Variance
Between Positions	3	2722.70	907.56	
Between Treatments	7	1253.26	179.03	
Interaction between positions & treatments	21	601.41	28.64	17.68
Total between sub-groups	31	4577.37		
Within sub-groups of four	88	142.12	1.62	
TOTAL	119	4719.49		

The interaction between positions and treatments is significant at the 0.1% level, therefore its variance is used as the error variance based on 21 degrees of freedom.

The variance of a difference between 2 means $= \frac{28.64}{4} \times 2$

Therefore, the standard deviation $= \left(\frac{28.64}{4} \times 2\right)^{\frac{1}{2}} = 3.785$

The 5% value of t for 21 degrees of freedom = 2.08

Therefore a difference of 3.785 x 2.08 = 7.87 is required for significance.

Table 2.21

Table of Treatment Means

Maximum Dry Bulb Temperature Increases.

TREATMENTS	POSITIONS I_1	I_3	II_1	II_3
1	22.65	8.65	23.02	5.75
h	21.65	10.05	21.55	7.02
f	14.20	3.97	13.62	2.50
F	19.92	11.20	20.20	6.97
Fh	18.42	12.42	17.40	8.47
fh	9.95	6.97	9.30	4.17
Ff	21.55	12.62	20.10	12.80
Ffh	13.60	11.17	11.05	8.92

At the 6" levels (positions I_3 and II_3) no significant differences occurred between treatment (1) (control) and any of the other seven treatments. However, it may be pointed out that there were significant differences between Ff and f for position I_3 between Ff and f, Ff and fh for position II_3. However, temperatures at this level are of little physiological importance only in as much as they have a bearing on the temperature gradient, limits for which have been recommended for rooms in continuous use (see Chapter 2).

At the 6'6" levels (positions I_1 and II_1) Ffh, fh and f produced significant reductions in peak values of the dry bulb temperature increases when compared with the control treatment.

Table 2.22

(b) Maximum H.R. Temperature Increases

TREATMENTS	POSITIONS															
	I_1				I_3				II_1				II_2			
1	25.2	25.0	27.3	26.8	9.0	10.1	11.2	9.7	26.2	25.7	28.0	27.1	8.1	7.9	8.4	8.8
h	26.7	23.7	25.4	23.7	13.1	12.0	12.8	11.3	25.0	24.8	25.1	23.5	10.9	10.1	10.3	9.2
f	15.1	14.9	16.4	16.7	4.8	1.8	4.2	5.1	17.6	17.8	19.4	18.2	4.3	0.9	3.2	2.3
F	24.7	25.6	24.3	23.4	12.1	12.3	13.2	11.9	25.1	26.2	24.3	23.5	8.2	10.5	9.2	9.6
Fh	17.8	22.1	25.4	22.3	12.4	14.5	15.6	15.0	19.1	20.1	22.8	21.3	9.9	10.8	12.2	11.8
fh	15.7	12.3	9.2	14.4	8.9	11.3	9.0	8.2	17.3	14.8	10.0	14.1	6.3	9.3	4.9	6.9
Ff	20.7	17.6	19.6*	19.3*	11.7	14.1	13.3*	12.6*	20.6	20.6	20.3*	19.7*	10.2	10.0	10.1*	10.3*
Ffh	13.3	15.6	14.6	14.2	10.7	14.1	11.3	11.7	13.4	12.9	13.6	11.1	8.7	10.5	8.9	9.6

* 8 values had to be estimated for treatment Ff.

Table 2.23

Analysis of Variance

Source of Variation	Sum of Squares.	Degrees of Freedom	Mean Square
Between positions	3442.33	3	1147.44
Between treatments	1129.86	7	161.41
Interaction of positions and treatments	823.92	21	39.23
Total between sub-groups	5396.11	31	174.07
(Within sub groups	186.07	88	2.11
= Error) Total	5582.18	119	

Between Positions	F	= 543.81	All significant
Between Treatments	F	= 76.5	at the 0.1%
Interaction	F	= 18.59	level of F.

In applying the t-test to the difference between the treatment means the interaction variance, based on 21 degrees of freedom is used as the error variance since it is significant in the above analysis.

The variance of a mean of 4 readings $= \frac{39.23}{4}$

Variance of the difference between 2 means $= \frac{39.23}{4} \times 2$

Standard deviation $= \left(\frac{39.23}{4} \times 2\right)^{\frac{1}{2}} = 4.43$

The 5% value of t for 21 degrees of freedom = 2.08

Difference of 2.08 x 4.43 = 9.2 is required for significance.

Table 2.24

Table of Treatment Means

Maximum Wet Bulb Temperature Increases.

TREATMENTS	POSITIONS I_1	I_3	II_1	II_3
l	26.1	10.0	26.7	8.3
h	24.9	12.3	24.6	10.1
f	15.8	5.9	18.2	2.7
F	24.5	12.4	24.8	9.4
Fh	21.9	14.4	20.8	11.2
fh	12.9	9.3	14.0	6.8
Ff	19.3	12.9	20.1	10.1
Ffh	14.4	11.9	12.8	9.4

It can be seen from this table that no significant effects were produced at the 6" levels (Pos I_3 and II_3).

However, treatments f (Pos I_1 only) fh and Ffh gave rise to a significant reduction in the peak values of the Wet Bulb temperatures at the 6' 6" levels.

Table 2.25

TREATMENTS	POSITIONS															
	I_1				I_3				II_1				II_3			
1	23	24	27	17	11	12	23	9	25	27	26	19	18	12	27	17
h	30	15	20	19	22	17	21	13	21	23	30	17	26	15	24	18
f	10	11	10	13	5	-4	10	8	28	29	26	26	6	2	7	-6
F	18	26	34	25	13	9	19	11	23	29	32	22	11	18	21	21
Fh	13	20	30	26	6	13	20	19	16	24	21	26	13	13	26	19
fh	31	24	8	13	16	22	14	11	34	23	20	18	14	24	12	12
Ff	12	15	15*	11*	7	17	17*	11*	15	15	16*	10*	10	12	11*	15*
Ffh	6	7	11	8	9	10	11	8	20	11	23	9	15	16	18	15

* Estimated values.

Table 2.26

Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom.	Mean Squares
Between positions	1507.15	3	502.38
Between treatments	1782.18	7	254.59
Interaction of positions and Treatments	1380.54	21	65.74
Total between sub-groups	4669.87	31	
Within sub- groups = Error	2642.25	88	30.02
TOTAL	7312.12		

Between positions $F = 16.73$ Significant at the 0.1% level of F

Between treatments $F = 8.48$

Interaction $F = 2.19$ Significant at the 1.0% level of F.

Interaction again significant therefore its variance must be used as the error variance.

∴ The variance of a mean of 4 readings $= \frac{65.74}{4}$

Standard deviation $= \left(65.74 \times \frac{2}{4}\right)^{\frac{1}{2}} = (32.87)^{\frac{1}{2}} = \underline{5.73}$

5% value of 5 for 21 degrees of freedom = 2.08

∴ Difference of $2.08 \times 5.73 = \pm 11.92$ required for significance.

Table 2.27

Treatment Means

Maximum Relative Humidity Increases.

TREATMENTS	POSITIONS I_1	I_3	II_1	II_3
1	22.7	13.7	24.0	18.5
h	21.0	18.0	22.7	20.7
f	11.0	4.7	27.0	2.0
F	26.0	13.0	26.5	18.0
Fh	22.0	4.5	21.7	18.0
fh	19.0	16.0	24.0	15.5
Ff	13.5	13.0	14.0	12.0
Ffh	8.0	9.5	15.7	16.0

It can be seen therefore that treatments Ffh and f produced significant results in the working space at the 6' 6" level. It also appears that f produced a significant effect at position II_3; this is probably a spurious result.

II. One method of ventilating a room, so far not considered, is that afforded by the intermittant opening and closing of the hopper and casement windows and the door. Such a procedure is commonly used by housewives in normal practice, providing external weather conditions, design and orientation of the room permit it.

Following the factorial experiment, experiments were carried out to study this effect. The procedures adopted were those of 4 housewives selected at random, who later participated as subjects in a series of experiments to study the changes in physiological reactions and subjective thermal sensations related to changes in room climate during domestic washing operations.

The figures obtained for $\sum_{t=o}^{t=255} (T^1 - To^1)$ and $\sum_{t=o}^{t=255} (H - Ho)$

for the two mid-level positions are shown in table 2.28.

Table 2.28

		REPETITIONS. (1)	(2)	(3)	(4)	Treatment Totals.	Treatment Mean.
D.B.°F.	POS. I_2	97.8	62.0	54.2	70.0	284.0	72.0
D.B.°F.	II_2	99.1	67.2	47.2	65.3	278.8	69.1
W.B.°F.	I_2	92.5	62.8	38.9	72.7	266.9	66.7
W.B.°F.	II_2	118.4	70.3	33.0	74.3	296.0	74.0
R.H.	I_1	54.0	16.0	65.0	59.0	64.0	16.0
R.H.	II_2	139.0	53.0	-15.0	82.0	259.0	64.75

An overall standard deviation for the difference between 2 means in order to compare this treatment with the previous treatments of the factorial experiments was calculated from the figures for all 9 treatments.

For a comparison of the mean increases of the three thermal factors for this treatment, which I have called (R), with those of the factorial experiment, one is referred to the following table giving the increases and the pooled standard deviation.

Table 2.29

Mean Increases of D.B. and W.B. Temperatures and Relative Humidity.

TREATMENT	DRY BULB °F.		WET BULB °F.		REL. HUMIDITY %	
	I_2	II_2	I_2	II_2	I_2	II_2
1	9.55	8.83	9.92	10.39	5.5	10.5
h	8.09	7.73	8.46	8.23	3.8	7.2
F	10.26	10.49	10.26	10.76	2.4	6.2
f	4.83	4.45	5.08	5.24	3.6	6.1
Fh	7.54	7.61	6.74	6.86	-1.5	-0.3
Ff	13.49	11.65	10.04	8.68	-4.8	-4.3
fh	3.99	3.78	3.97	3.60	1.7	1.2
Ffh	7.90	7.67	6.34	5.41	-8.1	-5.5
R	4.80	4.65	4.44	4.93	1.0	4.3
STANDARD DEVIATION	0.73	0.66	0.83	0.64	2.9	2.6

Using the value t = 2.074 based on 22 degrees of freedom the least differences necessary for significance (S.D. x t) are:-

	D.B.		W.B.		R.H	
POS	I_2	1.51°F	I_2	1.72°F.	I_2	6.0%
	II_2	1.37°F.	II_2	1.33°F.	II_2	5.4%

Table 2.20 shows that treatment (R) had a very significant effect upon the build up of wet and dry bulb temperatures in the two positions considered. At position I_2, together with the fan and the fan plus hopper window it produced the most significant reductions. The means for these two treatments and for (R) are not statistically different. At position II_2 the same result was found both with regard to wet

bulb and dry bulb temperature increases.

However, it produced no significant lowering of the relative humidity increases at position I_2 (in the working-space) but proved effective for position II_2 although inferior Ffh, Ff and Fh.

III. Air Change rates for Room 2.

A series of experiments were carried out after the factorial experiments to determine the number of room air changes per hour for the treatments (1) F, h and Fh for Room 2 using Room 1 (see plan) as a control.

Since the air change rate is dependent to some extent on the external wind velocity[16] [17], it was recorded, together with the direction, during each experiment. The air change rates were measured three times for each room and treatment.

CO_2 was introduced into each room from Douglas bags and the air change rate was calculated from the decay in the percentage of CO_2 in the room air over a 15 minute period, the concentration being measured four times at 5 minute intervals[18]. The results are summarised in the following table:-

Table 2.30

Air Change Rates for Rooms 1 and 2 for
Four Different Methods of Ventilation.

TREATMENT	External Wind Direction.	External Wind Mean Velocity (m.p.h.)	Air Change Rate (Room air changes per hour) Room 1 Vol: 1141 cu.ft.	Room 2 Vol. 1130 cu.ft.	Mean Value for Room 2.
(1) 1	-	0	0.79	0.78	
2	-	0	0.74	0.61	0.65
3	S.S.E.	8.7	1.56	1.15	
h 1	-	0	2.56	1.94	
2	S.E.	8.0	4.00	3.58	3.10
3	S.E.	7.6	5.62	3.52	
F 1	N	7.5	3.70	5.4	
2	S.S.E.	5.0	5.69	5.27	5.35
3	S.S.W.	8.0	3.71	5.39	
Fh 1	N	7.5	5.24	7.03	
2	S.W.	20.2	10.00	10.66	8.89
3	S.S.E.	8.0	5.44	7.0	

For both rooms the maximum air change rate was obtained with the hopper used in conjunction with the fire and the control treatment (1) produced the least number of air changes.

The dependence of the air change rate on the external wind velocity is not clearly shown from such a small number of observations.

However, the highest mean external wind velocity 20.2 m.p.h. observed during the second experiment for treatment Fh caused a significant increase in the air change rate for both rooms above the values calculated for experiments 1 and 3 for the same treatment.

The air change rates for the remaining treatments were not measured. The carbon dioxide decay method is limited to a maximum of approximately 12 room air changes per hour. Since the fan had an air delivery of approximately 18,000 cu.ft. per hour the number of room air changes would exceed the useful range of the experimental method for treatments f, fh and Ffh.

From the point of view of the vitiation of the room air, resulting from the combustion of the gas, observations made during the factorial experiments showed that even for the control treatment the CO_2 concentration never exceeded 1.0% at mid-level and 0.7% at burner level in the proximity of the gas wash boiler. Any presence of CO in the room could not be detected by the CO indicator Mark III (No. 1); such an instrument can readily detect the presence of CO to 1 part in 100,000. The upper physiologically safe limit for CO is 0.01%.

Conclusions

The following two tables, based on the preceeding analysis show those treatments which produced significant reductions of the increases in the three thermal factors considered.

Table 2.31

Showing Ventilation Methods which Produced
Significant Reductions of the Maximum Increases.

POSITION I_1			POSITION II_1		
6' 6" level in Working Space			6' 6" level in Remote Corner		
D.B. °F	W.B. °F.	R.H.%	D.B. °F	W.B. °F	R.H.%
fh) 12.70 Ffh) 9.05 f) 8.45	fh) 13.20 Ffh) 11.70 f) 10.30	Ffh) 14.7 f? 11.7	fh) 13.72 Ffh) 11.97 f) 9.40	Ffh) 13.90 fh) 12.70	-

Table 2.32

Showing Ventilation Methods which Produced
Significant Reductions of the Mean Increases
During the 255 minute experimental period.

POSITION I_2			POSITION II_2		
4' level in working space.			4' level in Remote Corner.		
D.B. °F	W.B. °F.	R.H.%	D.B. °F	W.B. °F	R.H.%
fh) 5.58 R) 5.45 f) 4.73 fh 2.02 Ffh 1.67	R) 6.00 fh) 5.95 f) 4.84 fh) 3.19 Ffh) 2.92	Ff) 10.0 Fh) 7.0	fh) 5.05 R) 4.99 f) 4.38	fh 6.78 R) 6.03 f) 5.15 Ffh) 4.97 Fh 3.53 h 2.16	Ffh) 16.0 Ff) 15.0 fh) 11.0 R) 9.0 fh) 9.0

Ff produced a significant increase of the D.B. temperature at Pos. I_2 of 3.94°F.

Ff (2.83°F) and F (1.86°F) produced significant increases of the D.B. Temperature at Pos. II_2.

In Table 2.31, the figures given with each significant treatment are the differences between the mean values from the four repeated tests of the maximum increase of the W.B. or D.B. temperatures or the relative humidity for treatment (1) (control) and the mean increase of the same factor for the treatment which it accompanies. In table

2.32 the figures given are the differences between the average values for the four tests of the mean increase during an experiment of the relevant thermal factor for treatment (1) and the mean increase of that same factor for the accompanying method of ventilation. The treatments have been arranged in the order of their significance; those of equal effect are bracketed together. Treatment (R) is not included in table 3.1 since there was only 1 instrument, at the 4' level in Position I during this particular test.

The results from the two 4' level positions have been subjected to a more detailed analysis since it is the temperature and humidity changes at these levels which will have the most significant effects on the physiological reactions and thermal sensations of a subject performing washing operations at position I and of a seated resting subject at position II.

The control of both wet bulb and dry bulb temperatures at this level in both positions can be achieved by a variety of different ventilating methods. Treatment R (the opening of windows and the door) is for obvious reasons the most economical method and the significance of such a treatment can be readily seen from table 2.32. Such a method therefore can be effectively used for temperature control and of course is most widely used in present day practice. The major complaint of housewives appears to be on the question of moisture control and the experiments have shown that treatment R does not provide for a reduction of the relative humidity increases which seems to substantiate the impressions gained from housewives. Furthermore, the opening of windows and doors to provide "through ventilation" of the working space is often impractical in winter time when adverse external weather conditions prevail. Therefore on these grounds an alternative method must be recommended for use during the winter time.

The 9" x 9" extractor fan, with an air delivery of 300 cu. ft. per minute, either on its own or in conjunction with the right hand hopper window is also seen from both tables to be an effective means of temperature control in both positions and of humidity control at position II_2. Although it produced a mean reduction of 11.7% in the peak value increase such a figure is barely significant when compared with the standard error. The interaction of these two factors was never significant from the analysis of variance. This was to be expected from their relative positions and furthermore, one would have thought that the effectiveness of the fan might have been reduced by the short circuiting of the air entering the hopper window to the fan. However, this appears not to have been the case. Therefore, an extractor fan, of the dimensions and air delivery used can be recommended for temperature and partial humidity control when external weather conditions deter the housewife from opening the windows and doors. It should be pointed out that simultaneous use of a fan of that power and of a coal fire with windows and doors closed should not be made because of the adverse conditions, already referred to, which might quickly develop in a kitchen of the size considered.

However, a result of particular interest is for treatment Fh (the fire and hopper window) which by virtue of the air change rate it effected provided significant reductions of all three thermal factors examined for both mid@level positions except for the dry bulb temperature increases at position II_2 which was nearer the fire. The reductions in temperature were significantly lower than for the methods already discussed above, but it did provide, to a certain extent, humidity control in the working space. Furthermore, it has been recommended in Post-War Building Studies No. 19[3] that a solid fuel flue should be provided in all modern kitchens in order to prevent the steam and odours which are generated in the kitchen from permeating the rest of the house. The present experiments have shown that in addition to this function a solid fuel fire can cause significant reductions of temperature, relative humidity and condensation created by the performance of a weekly family wash.

The fire plus the hopper window effected a mean of 8.89 room air changes per hour which was approximately 10,000 cu. ft. per hour. The extractor fan, if fully efficient under the experimental conditions was extracting 18,000 cu. ft. of air per hour.

In view of the findings of these recent experiments the minimum recommended air change rate of 18,000 cu. ft. per hour should be adopted for temperature control in kitchens of approximately 1,000 cu.ft. capacity during the performance of clothes washing. This can be achieved either by an extractor fan (air delivery 300 cu.ft/min) located in the immediate vicinity of the sink and gas wash boiler or, when external conditions permit it, by the full use of casement windows and external doors. Significant reductions of the increases of relative humidity may not be produced and considerable condensation may still occur when use is made of such methods.

However, it is further recommended that in winter time, since extractor fans are not normally installed in domestic kitchens or kitchen living rooms at the present time, the control of moisture and condensation can be achieved by making full use of a solid fuel flue in conjunction with a hopper or casement window. In the present experiments the air change rate effected by this method was 10,000 cu.ft. per hour. It achieved humidity control at positions I_2 and II_2 and reduced considerably the condensation at the expense of less control of the increases of wet and dry bulb temperatures than was produced by the two methods mentioned above. However, the increases of these factors were still significantly lower than the increases for the control treatments.

<u>Summary</u>

(1) A series of experiments have been carried out to study the effect of varying ventilation rates on D.B. and W.B. temperature and relative humidity increases and distribution resulting from the operation of a domestic gas wash boiler.

(2) The physical characteristics of the room were assessed at 6 points over a 255 minute period, during which time the gas boiler was lit for 75 minutes consuming on the average 54 cubic feet of gas.

(3) 8 different ventilation rates arising from all combinations of

Coal Fire		Hopper Window		Extractor Fan
Not Lit	x	Opened	x	Off
Lit		Closed		On

and the additional treatment afforded by the intermittent opening and closing of the hopper and casement windows and the door, according to the schedule of four housewives chosen at random, were considered.

(4) Special consideration was given to the two 4 ft. level positions.

(5) Air change rates by the CO_2 decay method were measured for the four treatments involving the Coal fire and the Right Hopper window.

(6) The room air was sampled at 2 levels to assess the CO and CO_2 concentrations at peak periods during the factorial experiment referred to in (3)

(7) Recommendations have been made for minimum air change rates for temperature control and attention has been paid to the control of moisture and condensation resulting from a gas wash boiler being lit for a 75 minute period.

CHAPTER III

User-Test Experiments.

Introduction

During the period June 19th to June 29th, 1951 a number of user-test experiments were carried out in Room 2, at the Thatched Barn Field Test Unit. These were essentially pilot experiments as a preliminary to a more detailed investigation into the physiological reactions of housewives performing routine domestic tasks in kitchen living rooms. They included a detailed survey of the horizontal and vertical distribution of humidity and temperature throughout the operation as well as physiological and subjective observations.

The standard domestic task in this investigation was that of performing a typical weekly wash for a family of four when using a moveable, domestic gas wash boiler. As in normal practice, this appliance had no direct lead to the external air with the result that the products of a combustion were free to be liberated and accumulate in the working space in the vicinity of the boiler unless controlled by a suitable method of ventilation.

The problem of the control of kitchen atmospheres during operations of this type in relation to external climatic conditions is by no means an easy one and these pilot experiments were especially designed in order to ascertain to what extent the conditions in the room can be controlled by the various devices available. Furthermore, the extent to which the atmosphere is controlled has an important bearing on the physiological reactions of the user and the importance of this point has been borne out by the results of these experiments.

In 1924 May R. Mayers[19] carried out an investigation into the working conditions and made certain physiological observations on workers in New York steam laundries. He found that with bad ventilating arrangements, temperatures and humidities ranged from 70°F, 60% R.H. to 90°F, 91% R.H. which, although not extremely high in themselves may have been harmful when added to the effect of prolonged and strenuous labour. He also suggested that strain could be measured in terms of changes in systolic and diastolic blood pressures.

For convenience, the scales for blood pressure (B.P.) in relation to age used by a New York Life Insurance Company were taken as standard and permitting a 12 per cent deviation he found many of the workers had abnormally high systolic blood pressures, pulse rates and pulse pressures and low diastolic pressures. There also appeared to be a definite relationship between working conditions in three different classes of laundries and the number of abnormal blood pressures found, but no apparent relationship between the percentage deviation from normal systolic and duration of employment.

Although the nature of the work done and the humidity and temperature levels are not so severe in kitchens during washing, the capacity of the worker is generally not so great. Therefore particular care is necessary to ensure that kitchen ventilation reduces environmental temperature and humidity changes to a minimum.

Method

(a) Physical Assessment

The experiments were divided into two series, the first comprising a rough physical check on the effectiveness of a newly installed

POSITION OF WINDOWS AND HOPPERS RELATIVE TO THE WORKING-SPACE.

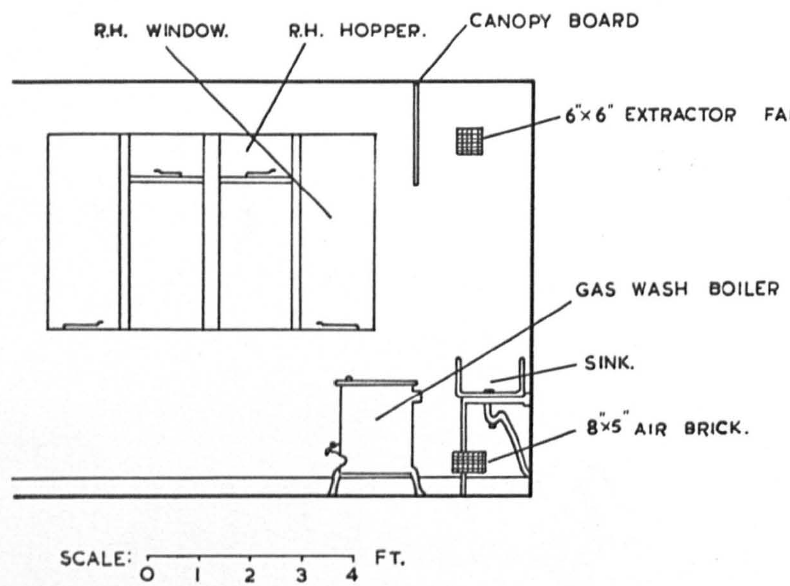


FIG. 3.1

6" x 6" fan extracting approximately 115 cu. ft. of room air per minute in conjunction with an 8" x 5" air brick vertically below it and a canopy extending over the working space. Fig. 3.1 shows the location of the gas boiler relative to the fan, air brick and windows. This arrangement relative to the sink and gas cooker is easily gauged from Fig. 2.3 which shows the arrangement for the factorial experiments.

This preliminary, purely physical survey occupied three days during which the build up and decay of temperature and humidity as a result of the gas boiler being lit for a 75 minute period was measured at 3 levels in positions I and II as described in Chapter II.

The distribution of temperature and humidity in the room was measured under 2 different conditions with the fan operating continuously and the air brick open.

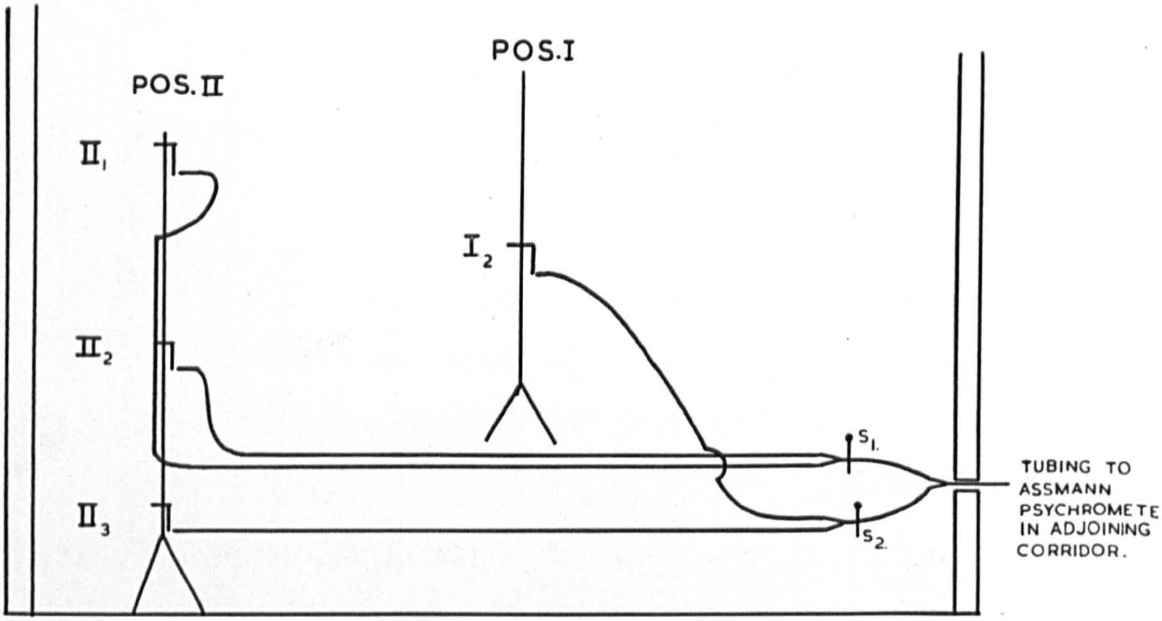
(a) Day 1. All windows and hoppers closed.

(b) Day 2. Right hand hopper open.

The conditions attained in these 2 tests could then be compared with those of the factorial experiments. From the combined results therefore the effectiveness of the present ventilating arrangement could be gauged.

The second series lasting four days comprised the actual user test during which the domestic task under investigation was carried out. For this, two subjects, whom we shall subsequently refer to as A and B, were used. A was a normal average housewife, whilst B was a trained domestic science operator. This series was further subdivided into 2 parts in the following way. Each subject performed the prescribed task of washing for a family of four on two separate

THE ASPIRATION OF THE WET AND DRY BULB ELEMENTS.



S_1 OPEN TO VENTILATE HYGROMETERS IN POSITIONS II_1 AND II_2
S_2 " " " " " " II_3 AND I_2

FIG. 3.2

occasions. On the first occasion she was at liberty to open windows and doors as she herself saw fit in order to maintain a comfortable working atmosphere. However, on the second occasion the subject was strictly limited in this respect, the right hand hopper only being opened. During both tests the extractor fan was running continuously.

A further slight modification was necessary for the user test experiments. In order that the apparatus for the physical assessment of the climatic conditions did not in any way impede the subjects in the execution of their tasks, the temperature and humidities were measured at the 4 ft. level only in Position I. Two instruments were ventilated simultaneously as shown in Fig. 3.2.

The subjects were requested to restrict their use of the gas wash boiler to as near the 75 minute period as possible.

Physical measurements were carried out at quarter-hourly periods from $t_1 = 0$ to $t = 195$ and subsequently every half an hour until the final reading at $t = 255$ minutes.

On the 11th July, 1951, a further purely physical assessment was carried out. The apparatus was again arranged as for the first series of experiments above, i.e., the humidities and temperatures measured at 6 points in the room. For the purposes of this test, thorough ventilation of the working space was achieved by having the door and casement windows opened by a fixed amount, namely that found desirable by subject A in her first user test, the only difference being that the fan was not used, its grill and the air brick below being sealed from the external air.

(b) Physiological data

In the assessment of the physiological state the following observations were made:-

1. Blood pressure.
2. Pulse rate.
3. Oral temperature.
4. Skin conductivity.
5. Skin temperature.
6. Respiration rate.
7. Subjective sensations of heat, moisture and freshness of the subject according to the following scales:-

Table 3.1.

Thermal Comfort Sensation Scales.

Heat Sensation	Index	Moisture. Sensation	Index	Freshness. Sensation	Index.
Unbearably hot	+7	Too moist (conscious sweating)	+ 5	Very stuffy	+ 2
Much too hot	+6	Moist (skin moist)	+ 4	Stuffy	+ 1
Too hot	+5	Too humid	+ 3	Comfortable	0
Hot	+ 4	Humid	+ 2	Fresh	-1
Too warm	+ 3	Comfortably humid	+ 1	Very fresh	-2
Warm	+ 2	Neutral	0		
Comfortably warm	+ 1	Comfortably dry	-1		
Neutral	0	Dry	-2		
Comfortably cool	-1	Too dry	-3		
Cool	-2				
Too cool	-3				
Cold	-4				
Too cold	-5				
Much too cold	-6				
Unbearably cold	-7				

The skin temperature was measured by means of a Moll thermopile which was calibrated in the experimental room. Skin conductivities were measured by the method of H. Barcroft and G.T.C. Hamilton (1948)[20] who described some experimental observations using the sudometer test after upper limb sympathectomy. The principle of this test is that the resistance to the passage of electric current through the body is almost entirely in the skin and is determined mainly by the activity of the sweat glands. This in its turn depends upon nervous excitation by the sympathetic[21].

A fixed electrode, consisting of a two inch square of copper gauze surrounded by cotton gauze soaked in normal saline was strapped to the axilla and using a 4.5 volt battery as a source of e.m.f., they found differences in current of the order of 40 microamps when a brass exploring electrode was held firstly in contact with the pads of the little fingers in which both ulnar nerves had been blocked (control) and then in contact with the pads of the thumbs of a number of subjects when maximal activity of the sweat glands had been induced.

It was thought that this principle might be applied, in the present experiments, to determine the time of onset of sweating and to give, if possible, a quantitative figure for the amount of sweat produced over any given area. The following areas were chosen:-

1. Forehead.
2. Front of upper arm.
3. Back of neck.

AREA COVERED BY MOLL THERMOPILE IN RELATION TO POINTS TESTED FOR SKIN CONDUCTIVITY.

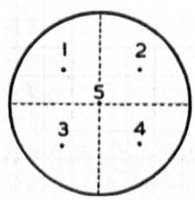


FIG. 3.3

The skin temperature was also determined for these three areas. Since the area covered by the Moll thermopile was relatively large the area of skin so covered was divided into 4 quadrants and 5 points as shown in Fig. 3.3. were selected for skin conductivity, the mean of the 5 readings being taken.

The circuit used is shown in Fig. 3.4. It consisted of the copper gauze fixed electrode which was strapped to the axilla with surgical tape connected through a 1.5 volt battery and galvanometer to the exploring electrode. Shunted across the galvanometer were two variable resistances 0 to 1 ohm and 0 to 10 ohms in series to increase the useful range of the apparatus.

The exploring electrode consisted of a spring loaded brass conductor inside an insulating handle. The brass electrode could then be applied with constant pressure to a flat surface. Preliminary experiments with an electrode of the type used by Bancroft and Hamilton showed that the current in the circuit was affected considerably by the pressure with which the exploring electrodes was applied.

The internal resistance of the galvanometer was 25 ohms and its sensitivity 0.5 cms. per microamp. Then if R is the value of the resistance in parallel with the galvanometer then the conductivity of the circuit is given by

$$\frac{1}{Rs + r} = \frac{25 + R}{1.5\,R} \times \frac{d}{2} \times 10^{-6} \text{ ohms}^{-1}$$

value d is the observed deflection in cms.

APPARATUS FOR THE ASSESSMENT OF SKIN CONDUCTIVITY.

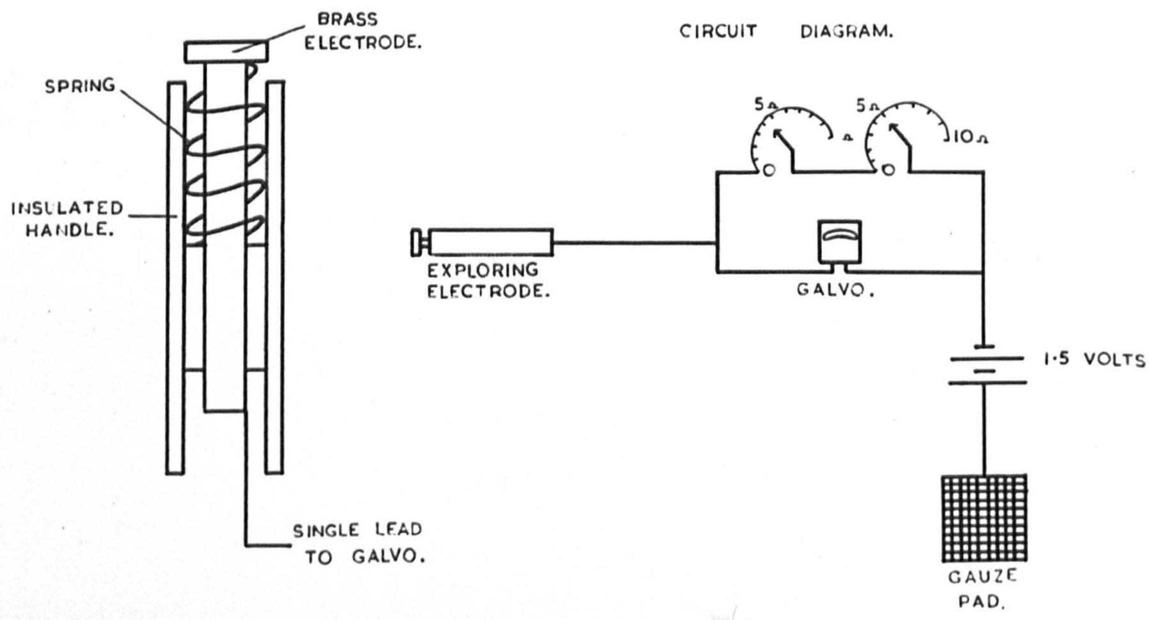


FIG. 3.4

Rs = skin resistance.

r = resistance of remainder of circuit

If Rs is very much greater than r, then

$$\frac{1}{Rs} = \frac{25+R}{1.5\ R} \times \frac{d}{2} \times 10^{-6} \text{ ohms}^{-1} = \text{skin conductivity.}$$

e.g. R = 1 ohm.

d = 10 cms.

$$\frac{1}{Rs} = \frac{26}{1.5} \times 5 \times 10^{-6} \text{ ohms}^{-1}$$

$$= 86.6 \times 10^{-6} \text{ ohms}^{-1}$$

The exploring electrode was kept in contact with the skin until a steady galvanometer reading was obtained. When the sweat glands were active a decrease in the value of the resistances in parallel with the galvanometer was made in order to secure a deflection on the scale. It was important that the subject remained quite still whilst the steady deflection was being obtained.

Prior to the experiment proper, the subjects' height and weight were recorded and the subjects' haemoglobin estimated.

Prior to each days' experiment the nature of the subjects' clothing and previous meal were ascertained.

The purpose of the observations on blood pressure and pulse rate was to obtain a value for the Crampton Index. This index is an index related to the state of the vaso motor tone which is related to the rise in pulse rate and the increase or decrease of blood pressure on changing from a lying to a standing position, the average normal value being over the range 70 to 80.

For purposes of calculating the value of the Crampton Index, the following scale was used[22],-

Table 3.2

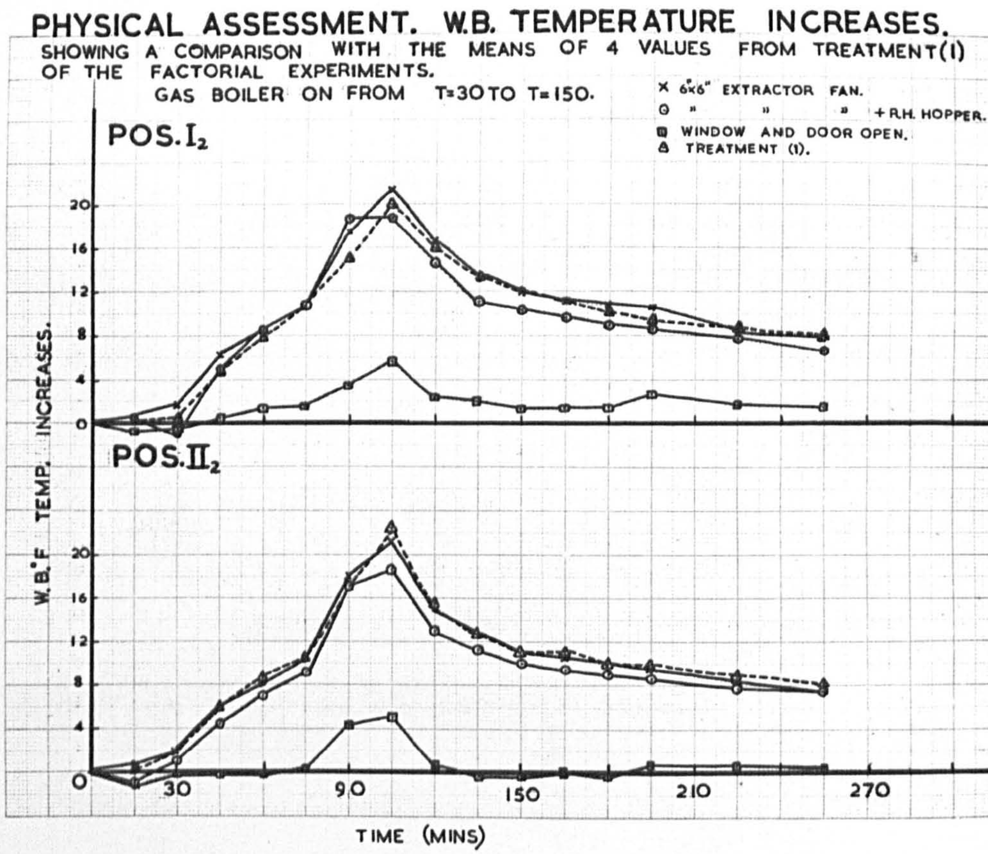
Scale of Gravity Resistance Value (Crampton)

Vaso motor tone Heart Rate Increase	SYSTOLIC BLOOD PRESSURE Increase +10	+8	+6	+4	+2	0	Decrease -2	-4	-6	-8	-10
0-4	100	95	90	85	80	75	70	65	60	55	50
5-8	95	90	85	80	75	70	65	60	55	50	45
9-12	90	85	80	75	70	65	60	55	50	45	40
13-16	85	80	75	70	65	60	55	50	45	40	35
17-20	80	75	70	65	60	55	50	45	40	35	30
21-24	75	70	65	60	55	50	45	40	35	30	25
25-28	70	65	60	55	50	45	40	35	30	25	20
29-32	65	60	55	50	45	40	35	30	25	20	15
33-36	60	55	50	45	40	35	30	25	20	15	10
37-40	55	50	45	40	35	30	25	20	15	10	5
41-44	50	45	40	35	30	25	20	15	10	5	0

For blood pressure increases greater than +10 add 5% to +10 column for each 2m.m. greater than 10.

The oral temperatures were obtained with the normal type clinical thermometer.

Before the commencement of the experiment on each day the subject spent 20 to 30 minutes sitting at rest in the room in which the experiment was to be carried out. Skin conductivity, temperature and oral temperature were taken together with observations of the blood pressure, pulse rate and respiration rate, first in a lying position and then in a standing position. Pulse and blood pressure readings were taken until two consecutive readings agreed. Also the subjective thermal sensations of the subject were recorded. These consistituted the base line or zero readings, from which subsequent changes were assessed.



PHYSICAL ASSESSMENT. W.B. TEMPERATURE INCREASES.
SHOWING A COMPARISON WITH THE MEANS OF 4 VALUES FROM TREATMENT(I) OF THE FACTORIAL EXPERIMENTS.
GAS BOILER ON FROM T=30 TO T=150.
× 6"×6" EXTRACTOR FAN.
⊙ " " " + R.H. HOPPER.
⊡ WINDOW AND DOOR OPEN.
△ TREATMENT (1).
POS. I_2
POS. II_2
W.B.°F. TEMP. INCREASES.
0
4
8
12
16
20
30
90
150
210
270
TIME (MINS)

FIG. 3.5

Similar observations to the above were taken at the following times:-

1. End of scrubbing period.

2. End of boiling clothes.

3. End of period during which subject had

   (a) taken lunch

   (b) used wringer

4. After hanging clothes and tidying the room.

5. At the end of 40 minutes rest in the experimental room.

In making these observations the following order of procedure was adopted:-

A. 1. Skin temperature) Taken with subject standing in
   2. Skin conductivity) the position at which she had
   3. Oral temperature) been previously working.

B. Subject lay in a supine position on a couch for a period of 2 minutes while the following observations were made:-

   1. Blood pressure.
   2. Pulse rate
   3. Respiration,

   until two consecutive readings were in agreement.

Subject then stood up and Series B was repeated until two consecutive readings of blood pressure and pulse rate agreed.

Results.

(a) The Physical Check.

Fig. 3.5 shows the increase in the wet bulb temperatures for the three experiments of the series under consideration, namely:-

(a) 6" x 6" extractor fan in conjunction with an 8" x 5" air brick vertically beneath it at the lowest possible level.

(b) Repeat of (a) with the right hand hopper window opened.

(c) Both casement windows opened $7\frac{1}{2}$", the right-hand hopper window fully opened and the door opened 18". The fan grill and the air brick were closed.

Since the results from (a) and (b) are plotted using the data from only one experiment in each case it was not possible to compare strictly the results with those plotted for treatment (1). However, this rough physical check does show that the 6" x 6" extractor fan was probably not an effective means of controlling the temperature increases in either position I_2 or II_2. Therefore, for the purposes of the pilot user test experiments from these results it was decided that the fan used in conjunction with the window hopper would provide a <u>control treatment</u> as opposed to the opening of windows and the door by the two subjects. This would achieve considerable differences in environmental changes on the two days for one subject. In other words, the ventilation by the newly installed fan and window hopper would probably not give rise to sufficient reduction in temperature and humidity increases as to cause any difference in the physiological reactions when compared with, say, treatment (h) (hopper open only) or treatment (a) as controls. These observations were confirmed in the user-test experiments and the data from experiment (c) which was conducted afterwards is also shown in Fig. 3.5.

TABLE 3.5.

Relative Humidity Increases.

TREATMENT	POSITION I_2 Peak Increase	Final Increase	Mean Increase	POSITION II_2 Peak Increase	Final Increase	Mean Increase
Fan only(a)	29	10	13.0	29	13	13.7
Fan plus hopper (b)	26	-2	7.0	21	-6	3.7
Window plus door (c)	-7	-10	-8.8	-4	-17	-9.8
Control (1)	13	6	9.8	20	12	9.8

Although Table 3.3. has not been drawn up in order that strict comparisons of the 4 treatments can be made it does show that the humidity increases indicate that either treatments (a) or (b) would be suitable as control treatments since the fan appeared to be an inadequate means of reducing the build up of relative humidity in both positions I_2 and II_2.

Conclusions

From this rough physical check it appeared that the fan alone was inadequate for temperature and humidity control and it was therefore decided to use the fan in conjunction with the right hand hopper window as a control treatment. Since these experiments were only of a preliminary nature, the subsequent pilot user tests would prove whether or not this was a satisfactory procedure to adopt in experiments to determine the effect of opening the door and windows as decided by the subjects. It was deduced from these pilot tests

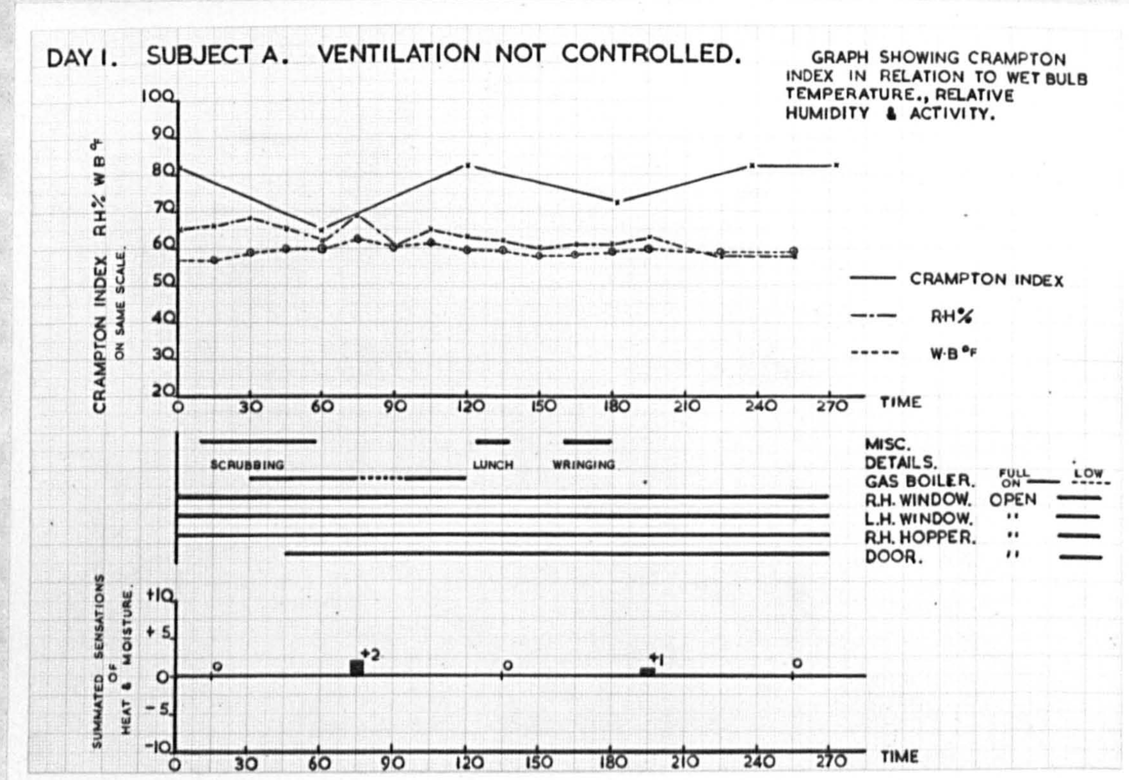

DAY I. SUBJECT A. VENTILATION NOT CONTROLLED.
GRAPH SHOWING CRAMPTON INDEX IN RELATION TO WET BULB TEMPERATURE., RELATIVE HUMIDITY & ACTIVITY.
CRAMPTON INDEX RH% W B °F
ON SAME SCALE.
100
90
80
70
60
50
40
30
20
0 30 60 90 120 150 180 210 240 270 TIME
CRAMPTON INDEX
RH%
W·B °F
SCRUBBING
LUNCH
WRINGING
MISC. DETAILS.
GAS BOILER. FULL ON LOW
R.H. WINDOW. OPEN
L.H. WINDOW. "
R.H. HOPPER. "
DOOR. "
SUMMATED SENSATIONS OF HEAT & MOISTURE.
+10
+5
0
-5
-10
+2
+1
0 30 60 90 120 150 180 210 240 270 TIME

FIG. 3.6

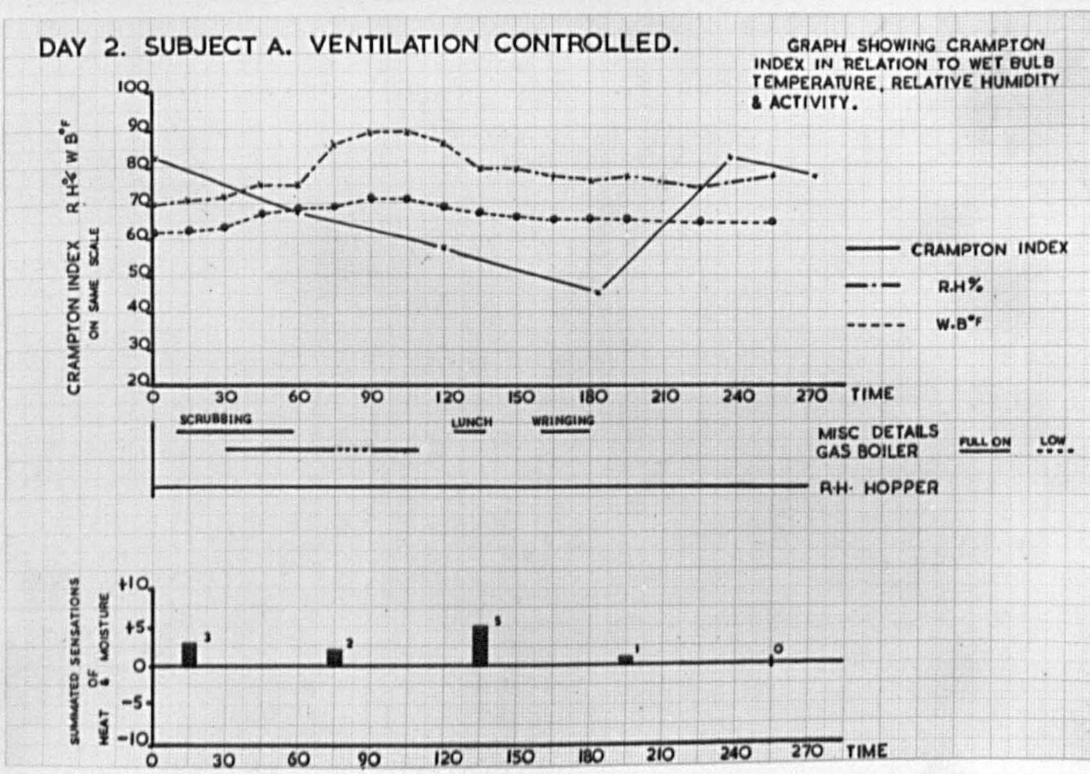

DAY 2. SUBJECT A. VENTILATION CONTROLLED.
GRAPH SHOWING CRAMPTON INDEX IN RELATION TO WET BULB TEMPERATURE, RELATIVE HUMIDITY & ACTIVITY.
CRAMPTON INDEX R H% W B °F
ON SAME SCALE
100
90
80
70
60
50
40
30
20
0 30 60 90 120 150 180 210 240 270 TIME
CRAMPTON INDEX
R.H%
W.B°F
SCRUBBING
LUNCH
WRINGING
MISC DETAILS
GAS BOILER FULL ON LOW
R·H· HOPPER
SUMMATED SENSATIONS OF HEAT & MOISTURE
+10
+5
0
-5
-10
3
2
5
1
0
0 30 60 90 120 150 180 210 240 270 TIME

FIG. 3.7

that this comparison would reveal sufficient differences in the increases of temperature and humidity as to cause significant differences in physiological reactions.

(b) <u>The User test experiments.</u>

Since the degree of activity of each subject during any one experiment was not constant the results show that there is no strict correlation between relative humidity or wet bulb temperature at position X_2 and Crampton Index. However, there were definite significant differences for both subjects in their Crampton indices between the days on which the ventilation was strictly controlled (fan working and right hand hopper open only) and the days on which the subjects were at liberty to open the door and casement windows as they saw fit. These differences, which followed the same general trends for both subjects must be attributed to the environmental differences in temperature and humidity and air movement as shown by the graphs (Figs. 3.6., 3.7., 3.8., and 3.9).

The following table gives a good indication of the effect of the effective temperature on Crampton Index at certain times during each experiment.

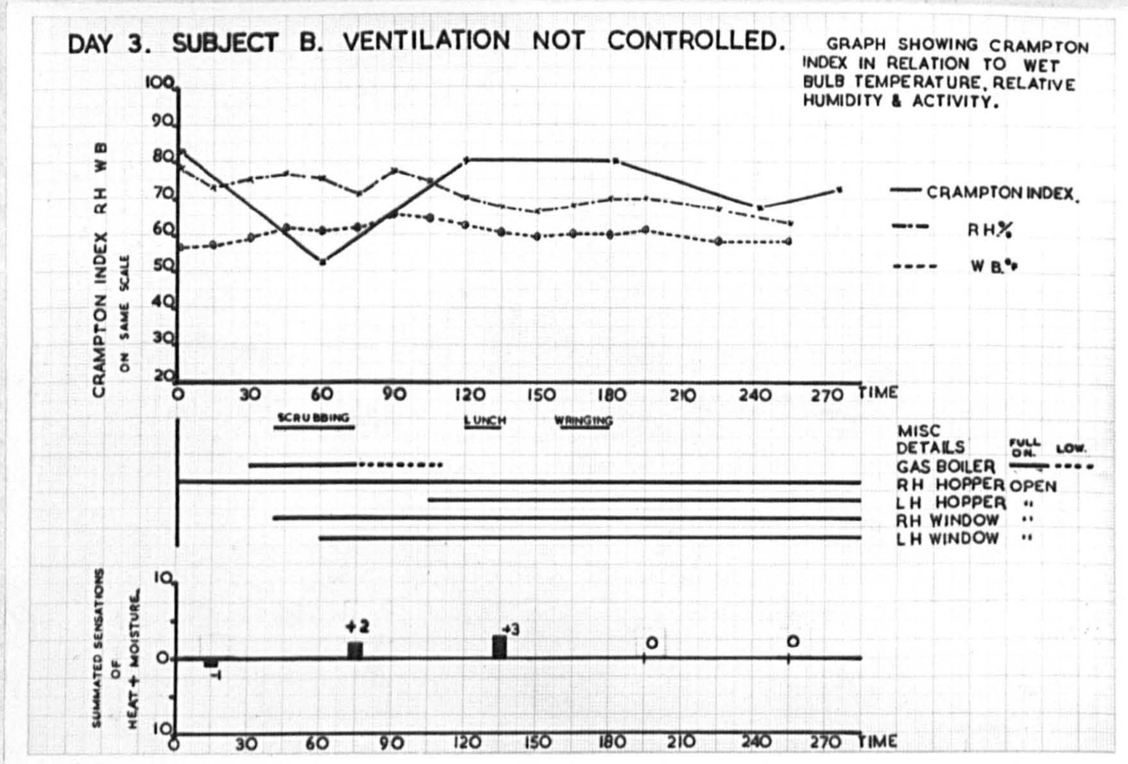

DAY 3. SUBJECT B. VENTILATION NOT CONTROLLED.
GRAPH SHOWING CRAMPTON INDEX IN RELATION TO WET BULB TEMPERATURE, RELATIVE HUMIDITY & ACTIVITY.
CRAMPTON INDEX RH WB
ON SAME SCALE
CRAMPTON INDEX.
RH%
W.B.°F
TIME
SCRUBBING
LUNCH
WRINGING
MISC DETAILS
FULL ON.
LOW.
GAS BOILER
RH HOPPER OPEN
LH HOPPER "
RH WINDOW "
LH WINDOW "
SUMMATED SENSATIONS OF HEAT + MOISTURE
+2
+3
-1
0
0

FIG. 3.8.

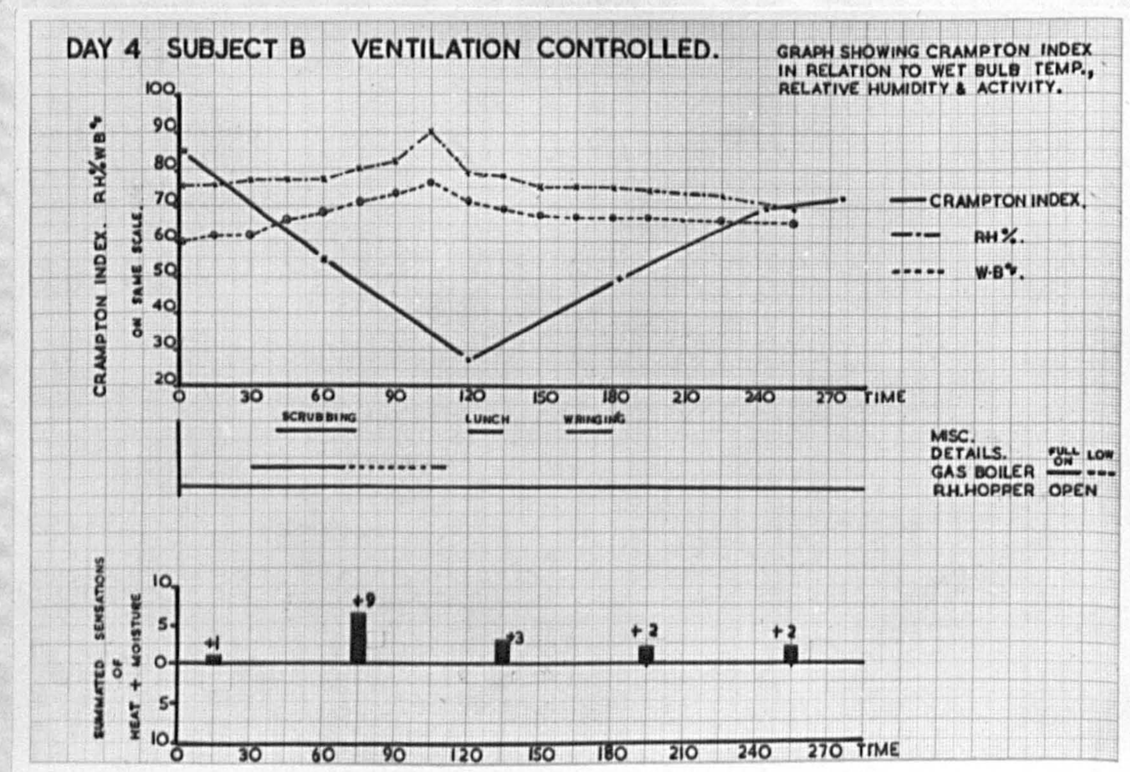

DAY 4 SUBJECT B VENTILATION CONTROLLED.
GRAPH SHOWING CRAMPTON INDEX IN RELATION TO WET BULB TEMP., RELATIVE HUMIDITY & ACTIVITY.
CRAMPTON INDEX. RH% WB°F
ON SAME SCALE.
CRAMPTON INDEX.
RH%.
W.B.°F.
TIME
SCRUBBING
LUNCH
WRINGING
MISC. DETAILS.
FULL ON
LOW
GAS BOILER
R.H.HOPPER OPEN
SUMMATED SENSATIONS OF HEAT + MOISTURE
+1
+9
+3
+2
+2

FIG. 3.9.

TABLE 3.4

Changes in Crampton Index for Subjects A and B and Effective Temperature.

	SUBJECT A				SUBJECT B			
	Day 1		Day 2		Day 1		Day 2	
Time.	Effective Temp.	Crampton Index	Effective Temp.	Crampton Index	Effective Temp.	Crampton Index	Effective Temp.	Crampton Index
0	57.8	82.5	60.5	82.5	57.1	82.5	64.0	85.0
60	62.0	65.0	66.7	67.5				
75					62.0	52.5	73.2	55.0
120	62.0	82.5	67.5	57.5	63.0	80.0	74.1	27.5
185	60.8	72.5	64.0	45.0	60.5	80.0	71.0	50.0
236	61.3	82.5	63.0	82.5				
245					59.0	67.5	70.0	70.0
275	61.0	82.5	63.1	77.5				
280					59.2	72.5	69.8	72.5
	Ventilation arranged by subject.		Ventilation by fan plus hopper only		Ventilation arranged by subject.		Ventilation by fan plus hopper only.	

A survey of air velocities at various points in the room for the treatments on Days 1 and 2 had previously shown that on Day 1 the mean air velocity would be approximately 10ft. per minute and on Day 2 200 fit. per minute at the 4 ft. level in the working space. Using these figures, the effective temperatures have been calculated and Table 3.4 shows the differences between values on Days 1 and 2 for both subjects associated with which are significant differences in the Crampton Index observations. The effective temperature is evaluated into a single index from combinations of temperature, humidity and Table air movement and it was found that various physiological responses were apparently stimulated by and related to this Index. (Yaglou, 1927)[23].

The comfort zone in the normal scale of effective temperature for persons <u>at rest</u> has been shown to be between 63° and 71°. Vernon (1927)[24] argued that the Effective temperature index did not hold when heavy muscular work was being done since sweating would cause subjects to be more sensitive to W.B. temperature. Yaglou at first tended to agree with this since the scale had originally been developed using a subject performing light work. However, experiments at Pittsburgh[25] proved that the index was not substantially altered with heavy muscular work. Correlations of Effective temperature with Rectal temperature increases per hour and rate of increase of pulse rate per minute per hour were as close as when subjects were at rest. There were practically no changes in the physiological reactions until the Effective temperature reached 75° which appeared to be the upper limit of man's ability to fully compensate for external temperature whilst doing heavy muscular work.

Table 3.4 shows that on no occasion did the Effective temperature exceed 75° but the differences between Days 1 and 2 were significant for both subjects.

For subjects A and B the effective temperature never exceeded 63° on Day 1 and the minimum observed Crampton Indices were 65 and 50 respectively. For Day 2 however, temperatures were considerably higher, reaching 67.5° and 74.1° for A and B. Associated with these higher temperature increases were more marked falls in the Crampton

Index to 45 for Subject A and 25 for Subject B. Furthermore, both subjects complained of fatigue at just those times when these low index values were observed.

Also associated with these falls in Crampton Index were increases in the subjective thermal sensations of the subjects. This fact is shown on the graphs which give observed values of the summated sensations of Heat plus Moisture as assessed from the scale of Table 3.1 at various times throughout the experimental period. Crowden and Lee (1940)[26] have shown that a high degree of correlation exists between these summated sensations and both wet bulb temperature and total heat of the air.

Temperature Gradients.

An environment which is considerably warmer at head level than at the foot level tends to produce a feeling of stuffiness whilst at the same time keeping the feet cool. It has been recommended that in rooms used for continuous occupation the D.B. air temperature at head level (5 feet) should not be more than 5°F higher than at feet level. Of course, comparisons in this respect could only be made for Position II. Table 3.5 shows the initial, peak and final temperature gradients between the 6'6" and 6" levels.

Table 3.5
Temperature gradients °F in the Working Space
(between 6" and 6'6" levels).

	SUBJECT A		SUBJECT B	
	Day 1	Day 2	Day 1	Day 2
Initial	1.4	1.8	1.7	2.2
Peak	2.8	7.7*	5.1	10.1**
Final	2.2	1.4	1.4	3.8

* Gradient exceeded 5.9°F from T = 75 to T = 105 mins.
** " " 5.2°F " T = 45 to T = 135 mins.

The table shows that the gradients at all times were within the specified range only on the days when the subjects were controlling the ventilation rates by opening the casement windows and in the case of Subject A, the door as well.

Skin Temperatures.

The discrepancy caused by sweating in the measurement of skin temperature by the Moll thermopile, both from considerations of absorption of infra-red radiation by, and the temperature gradient across the moist layer are negligible when compared with the accuracy of the instrument for the measurement of surface temperatures.

Increases in forehead skin temperatures are associated with increases in D.B. air temperature. Bedford (1935)[27] showed that on the average the forehead temperature rose by 0.23°F for a rise of 1°F in D.B. air temperature at the 4 ft. level in the range 55°F to 75°F. His observations were made on nearly 2,000 subjects performing light industrial tasks. In a gradually increasing environmental temperature a momentary fall in skin temperature would be associated with the onset of sweating followed by a slower increase as a result of further increases in D.B. air temperature.

The forehead temperatures recorded in the present experiments, because of the small time available for this observation were too infrequent and the increases in temperature so steep that this phenomenon could not be observed.

The ranges in forehead temperatures for both subjects were as follows:

Table 3.6

Subject's Forehead Skin Temperatures °F.

SUBJECT A	Time: mins:-	0	60	120	185	236	275	Mean Values
Day 1	Forehead temp.	93.5	96.8	94.3	95.7	96.0	95.5	95.3 ±1.44
	D.B. Temp.	64.1	68.7	68.7	67.4	68.1	68.7	
Day 2	Forehead temp.	92.0	94.6	96.0	95.5	94.8	95.4	94.7 ±2.03.
	D.B. temp.	62.0	68.1	68.7	65.7	64.5	64.3	
SUBJECT B	Time: mins:-	0	75	120	185	245	280	
Day 1	Forehead temp.	93.1	91.3	90.6	92.4	90.5	94.8	92.1 ±2.76
	D.B. temp.	61.1	68.3	69.2	66.8	65.7	66.1	
Day 2	Forehead temp.	94.2	93.8	92.8	91.8	93.1	94.3	93.3 ±0.09
	D.B. temp.	65.2	75.7	76.3	73.4	72.5	72.7	

The day differences between the means for both subjects were not significant. The daily variations did not appear to be well correlated with D.B. temperature variations at the 4 ft. level and this was to be expected since this temperature alone did not adequately describe the thermal conditions to which the subjects were exposed. Temperatures of the back of neck and forearm also gave no significant differences between days.

Skin Conductivity.

The apparatus employed, whilst not giving a quantitative measure of sweat produced, demonstrated well the onset of sweating. The appearance of sweat on the forehead resulted in a marked increased conductivity as measured. Table 3.7 shows the measures in skin conductivity in the two days for both subjects. Each figure is the mean from the five readings obtained for each area.

Table 3.7

Subjects' Forehead Skin Conductivities.

($ohms^{-1} \times 10^{-6}$)

SUBJECT A.

Time (mins.)	Forehead Day 1	Forehead Day 2	Left Forearm Day 1	Left Forearm Day 2	Back of Neck Day 1	Back of Neck Day 2
60	-0.6	+41.4	No measurable increases.			
120	+ 4.5	+78.8				
185	+66.8	+50.2				
236	+ 70.7	+41.5				
275	+61.1	+50.4				

SUBJECT B

Time (mins.)	Forehead Day 1	Forehead Day 2	Left Forearm Day 1	Left Forearm Day 2	Back of Neck Day 1	Back of Neck Day 2
75	+57.1	+133.1	+3.2	+6.8	+ 7.8	+87.0
120	+70.9	+133.1	+3.9	+4.1	+10.8	+42.7
185	+16.3	+123.8	+1.2	+2.6	+ 3.3	+10.8
245	+21.5	+ 88.4	+1.3	+2.2	+ 1.3	+16.4
280	+10.6	+ 26.2	- 0.2	- 0.8	+ 2.5	+ 4.0

Onset of Sweating:-

(a) Forehead

Subject A:- Day 1. Onset occurred whilst subject was using the wringer after she had remarked that it was difficult to use.

Day 2. Commenced sweating on forehead as a result of scrubbing.

Subject B:- Day 1. Subject's sweating increased as a result of scrubbing, reaching a maximum at T = 120 mins.

Day 2. Showed same trends as, but greater increases than on Day 1.

(b) Forearms and Back of Neck

Subject A showed no perceptible indications of sweating in these areas on either day. There were no measurable increases in conductivity.

Subject B showed a trend with skin temperature being more marked on back of neck than on forearm.

Oral Temperatures.

Subject A:- The maximum difference between the two days was 0.8°F being higher on the first day (99.0°F). The maximum change in any one day was 1.0°F occurring on the second day.

Subject B:- The maximum difference between the two days was 1.6°F being higher on the second day (98.8°F). The maximum change in any one day was 1.3°F occurring on the first day.

The two subjects were opposite in both respects and nothing significant as regards oral temperatures could be obtained from the limited number of readings taken in these experiments. Furthermore, there appeared to be no correlation between oral temperature and Crampton Index under the experimental conditions that existed.

Respiration.

No useful information was obtained.

Conclusions.

In these pilot experiments, one of the most important results from the physiological standpoint was that the lowering of the vaso motor tone of both subjects during periods of maximum activity was much more marked on the days when the temperature and humidity were higher. During the days when the subjects themselves controlled the ventilation, the D.B. temperature never exceeded 71°F. and the relative humidity for subjects A and B never exceeded 70% and 80% respectively. The maximum decrease in their Crampton indices caused by scrubbing was 17.5% for A and 30% for B. On the other hand, when the ventilation was strictly controlled, humidities reached 90% and the dry bulb temperatures 72.0°F. and 79.1°F. for A and B. In this case, the decreases in Crampton index were A, 36.5% and B, 57.5%. The difference in environmental conditions on the two days was much greater for Subject B as shown in Table 3.4, and this appeared to cause a larger decrease in the Crampton index on Day 2. For both subjects during their first tests the vaso motor tone was within the normal limits except during the scrubbing period. This was not the case during the second experiments when a minimum was reached prior to lunch time by Subject B and after the wringing period for Subject A.

Both subjects remarked that working conditions were comfortable throughout when they could do as they pleased, but it should be noted that Subject B did not open the door. Furthermore, the physical conditions which similated the ventilation employed by Subject A showed that the fan could be dispensed with. However, when only the right hopper was opened and the fan operating, both subjects were most uncomfortable. They considered that the conditions were stuffy, too warm and much too damp.

From these results obtained in these pilot experiments any strict correlation of physiological and physical data has not been possible, but it was clearly indicated that the physical environment had a very important bearing on the reactions and fatigue sensations of the subjects.

It appears, therefore, that the most important finding from this series of experiments was that physically and physiologically under internal summer conditions in temperate regions (D.B. 55°F. to 70°F) when full use is made of windows and doors, (design permitting), as sources of ventilation a comfortable working atmosphere is attainable throughout the period of activity in the operation of domestic washing involving the use of a gas wash boiler in a room of the size employed in these user tests.

Furthermore, the marked differences in physiological reactions and increases in temperature and humidity in the room together with the opinions of the two subjects showed that a 6" x 6" fan extracting 115 cu.ft. of air per minute was not an effective means of maintaining a comfortable working atmosphere in the room.

Discussion.

Leonard Hill (1895)[28] first introduced arguments in support of reactions to postural change as a test of physical condition. The splanchnic area can hold a very large proportion of the blood in the human body and on changing posture from lying to erect position a large amount of blood would collect there if it were not held in control by vaso constriction. If this constriction did not take place a marked lowering of the blood pressure would occur and if it was excessive the blood pressure would rise. In fit and healthy young people it was found that the effect of gravity was usually over compensated for and the assumption of an erect position was accompanied by a slight increase in blood pressure. It was argued, further, that in fatigued persons the vaso motor mechanism failed to react properly and an increase in the heart rate occurred in an effort to counteract diminished tension in the blood vessel walls.

Crampton (1905)(29) (30) (31) (32) (33) was of this opinion. He also argued that increased ventricular contraction would cause a rise in the immediate maximum blood pressure in the arteries since the blood would be forced more abruptly into them, but unless there was also an increase in the heart rate there would not be any marked increase in the mean arterial pressure. This was further substatiated by Erlanger and Hooker (1904)(34) who held that the pressure would be low for a longer period than it was high in any one cardiac cycle.

In Crampton's Blood Ptosis test it was assumed that the arguments first proposed by Leonard Hill were correct. It was long appreciated that the simplest way to test the circulation was to note its reaction to a standard amount of work. Crampton's standard load imposed upon the circulation was a simple and entirely natural one. The test consisted in observing the reaction of the circulation to the load placed upon it when the subject actively rose from a horizontal to a vertical position. For, in the horizontal position circulation occurs in one plane only but on rising the blood must return from the lower half of the body against gravitational attraction. The mechanisms for carrying out this process are:-

(a) Contraction of the leg muscles upon the veins.

(b) Increase in abdominal tension.

(c) The muscles in the walls of the veins, particularly of the splanchnic veins acting to prevent an accummulation of blood in the splanchnic region as previously mentioned.

In constructing his scale, Crampton took the records of several hundred normal fit young men and found that the total range of the observations were from +10 to -10 mm.Hg. of systolic pressure and from 0 to 44 increases in heart beats per minute on actively rising to the vertical position. Furthermore, since he found these ranges to be statistically equal they were assigned equal values and each divided into 50 steps with the fair assumption that these steps were equal in significance. These figures constituted his original scale which had been derived from normal subjects. However, this did not prove to be a complete scale since records from very sick and fatigued persons soon demonstrated the necessity for extending it. This was done, the scale being extended in both directions using the same measures as had been standardised for normal subjects and Crampton considered the scale as being a useful and convenient method of stating approximately the condition of the gravity resisting mechanism of the human body in terms of a single index.

Evidence has accummulated, however, to show that in the normal rested state there is practically no postural change in systolic blood pressure in well conditioned athletes but in poorly conditioned people the change is either positive or negative, instability being indicative of poor control of the splanchnic control mechanism. This showed therefore that the Crampton Index was of questionable value. Several workers have studied the Index as a test for endurance or physical fitness. Scott(35) used the index on 410 men at Mitchell Field, U.S.A. in 1921. He found that it could not separate those men physically qualified to fly from those who were not. The

Schneider Test[36] [37] did. This test also assigns relative values on an emperical basis to each item in a combined test to yield an arbitrary point score. This test was an attempt to combine the best features of the Crampton test with the McCurdy pulse rate increase test on standing and the Foster pulse acceleration test resulting from exercise. Since exercise formed an integral part of the assessment it was not suitable for the present series of experiments where it was essential that interference with the subjects routine should be reduced to a minimum. However, it may be that absolute values for the Crampton Index are of questionable validity and that it does not provide a suitable criterion for comparing different subjects. On the other hand, it may prove to be a most useful means of revealing changes in circulatory efficiency and general physiological well-being, based on changes in the value of the index for any one individual in a series of experiments of the type carried out in the present study.

Several attempts have been made to improve the many tests of physical efficiency. The idea has persisted that some combination of blood pressure, pulse pressure and pulse rate giving an Index would give a better indication of condition than any one component taken separately.

For this purpose, 3 techniques were used, namely:-

(a) Product or ratio technique. Erlanger-Hooker (P.P. x P.R.) Index (1904), Stone test (1913) Barach test (1914) Tigerstedt index.

(b) The Emperical Weighting scheme. Crampton (1905), Foster (1914) Schneider (1920) Lamb (1930).

(c) Statistical weighting in a Multiple Regression Equation for optimum prediction. Read (1922) Sale (1931) McCloy (1931) Larson (1935).

In 1937 Larson showed that standing tests were more valid than sitting tests and that B.P. could be considered a more valuable index than pulse rate. This work, however, was never published, but studies carried out have shown that those indices containing both blood pressure and pulse rate are better correlated with athletic ability than indices containing blood pressures only.

The Crampton index is compared below with changes in 3 other Indices which could be readily assessed under the experimental conditions that prevailed. The indices were:-

(a) The Erlanger-Hooker (Pulse pressure x pulse rate) index. During exercise or immediately after, it is considered to be approximately equal to the heart output. The difficulty is in obtaining the correct values for blood pressure and pulse rate as both components drop very rapidly after exercise.
It has been criticised on the grounds that fitness is usually associated with low, rather than high, pulse rates.

(b) The Stone Index $= \dfrac{\text{Pulse pressure}}{\text{Diastolic B.P.}}$ (Standing)

(c) The Tigerstedt Index $= \dfrac{\text{Pulse pressure}}{\text{Systolic B.P.}}$ (standing)

The reasoning for both (b) and (c) is based on the assumption that the pulse pressure should average ½ diastolic B.P. plus 1/3rd systolic B.P. Neither index has appeared to give any significant correlations with endurance criteria.

Table 3.8 gives the changes in these indices for the subjects in relation to their resting values observed on Day 1 and Day 2.

Table 3.8

Changes in the magnitude and sign of physical fitness indices in relation to resting values.

SUBJECT A

Phase of Experiment	Crampton Index Day 1	Crampton Index Day 2	Erlanger-Hooker Index Day 1	Erlanger-Hooker Index Day 2	Stone Index Day 1	Stone Index Day 2	Tigerstedt Index Day 1	Tigerstedt Index Day 2
After scrubbing	-17.5	-15.0	+132	+450	-.13	0	-.06	0
Before lunch	0	-17.5	+112	+20	-.12	-.02	-.05	-.02
After wringing	-10.0	-37.5	-38	+ 70	-.17	-.08	-.08	-.04
After hanging out	0	0	-248	-410	-.15	-.08	-.07	-.04
After rest period	0	-5.0	-397	-290	-.11	-.08	-.05	-.04

SUBJECT B

Phase of Experiment	Crampton Index Day 1	Crampton Index Day 2	Erlanger-Hooker Index Day 1	Erlanger-Hooker Index Day 2	Stone Index Day 1	Stone Index Day 2	Tigerstedt Index. Day 1	Tigerstedt Index. Day 2
After scrubbing	-30	-30	-640	+650	-.21	+.07	-.08	+.02
Before lunch	-2.5	-57.5	-1760	-1140	-.27	-.22	-.12	-.11
After wringing	-2.5	-35.0	-1440	+420	-.27	-.03	-.10	-.02
After hanging out	-15.0	-.15.0	-2190	-20	-.21	-.05	-.08	-.11
After rest period	+10.0	-12.5	-3090	-900	-.32	+.01	-.13	0

For the Crampton Index, the changes during any one experiment and the differences between the two days have already been discussed. With regard to the other indices it is of particular interest to consider both subjects separately:-

1. Subject A: The three indices other than the Crampton suggested that on the basis of normal ranges the subject was more fatigued on Day 1 than on Day 2. This was the exact converse of the opinion of the subject and was not consistent with the differences in environmental conditions on the two days.

2. Subject B: Generally speaking the changes in the indices justified the same conclusions as for Subject A particularly so in the case of the Stone Index.

Consideration of these findings showed that these 3 indices were not suitable for use in the present study as physiological indices in experiments in which the physiological and subjective effects of changes in environmental temperature and humidity were to be assessed.

In 1923, however, the New York State Commission on Ventilation[38] used the Crampton Index as a gauge of physiological reactions to atmospheric conditions. Critics were inclined to agree that the normal range of 70 to 80 was too high but that relative figures might be significant. The Commission took observations from many subjects of the final value after, and changes in the Crampton Index, during four and eight hourly exposures to different temperatures and humidities. They found that exposures to higher temperatures and humidities resulted in a lowering of the Crampton Index. Also, comparisons in the changes in diastolic blood pressure with changes in pulse rate x pulse pressure showed that the actual work done by the heart was unchanged in the atmosphere considered but that exposures to higher temperatures decreased the peripheral resistance.

The blood pressure depends upon the cardiac output and peripheral resistance, the latter consisting of the skin and splanchnic vessels. Now Crampton considered that changes were greatest within the splanchnic vessels and for a subject at rest in a constant environmental effective temperature this may well be so. However, when a subject is exercising in changing environmental conditions of temperature and humidity the skin vessels cannot be neglected. Therefore, the greater the dilatation by the skin vessels the less the compensation afforded by splanchnic constriction. An alteration in resting pulse may be associated with environmental changes, consequently, a low Crampton Index does not necessarily mean a deficiency in vaso motor tone. However, when the Index fell the subjective sensations showed the same general trends.

These pilot experiments indicated the nature of the observations which it would be worth while to make in later full scale experiments and field studies. The following recommendations for future experiments were formulated on the basis of the experience gained in these pilot studies:-

(a) Physical. 1. Temperature, humidity and air movement in the working space, bearing in mind that the position chosen must not in any way interfere with the housewife in the execution of her domestic tasks.

2. Temperature gradient humidity and air movement in a remote corner of the room where perhaps a second occupant may be located.

3. External temperature, humidity and wind.

(b) Physiological.

1. Blood pressure and pulse rate in the supine and standing positions.

2. Skin forehead temperatures using the Moll thermopile might give interesting results if observations could be carried out on a large number of subjects.

3. Skin conductivity. The apparatus used, whilst not accurate for an absolute measure of the amount of sweat on the skin surface, since it gives not only an indication of the presence of sweat actually on the surface but also in the sweat glands, in addition possibly, to an increased peripheral blood flow component, did yield very useful information as to the onset of sweating and a rough measure of relative sweating rates. Frequent observations would be necessary to establish the exact time of onset of sweating.

Difference between Subjects.

The figures showed that there was a difference in the changes in vaso motor tone, skin surface temperature and relative sweating rates of the two subjects.

Subject A was 30 years of age; Subject B was 47.

Summary.

A number of pilot experiments have been conducted to examine certain physiological reactions of two subjects performing the routine domestic task of clothes washing in a kitchen living room at the Field Test Unit, Thatched Barn, and at the same time the horizontal and vertical distributions of temperature and humidity in the room were observed.

The effects on indices of the vaso motor tones of the two subjects due to differences in the environmental conditions caused by variations of the ventilation rates of the room have been described and the use of the Crampton Index is discussed.

The findings of this pilot study indicated which observations were worth while taking in future full-scale user-test experiments and the experimental routine which could be carried out with minimum disturbance to the subjects in performing the specified task.

CHAPTER IV.

The Full Scale User-Test Experiments

The results of the pilot experiments concerning the physiological reactions of housewives performing a typical weekly wash for a family of four persons when using a movable domestic gas wash boiler gave a definite indication that the extent to which the atmosphere in the room is controlled has an important bearing on the physiological reactions and subjective thermal and fatigue sensations, of the user. In the light of the results of these preliminary experiments it was decided to carry out a further series of experiments on the same problem with, however, several differences and improvements in technique.

The most important difference was the presence of a control subject situated in position II. Furthermore, four working subjects were employed making 8 experiments in all.

Since skin surface temperatures and skin conductivity of the forearm and back of neck regions yielded no useful data in the pilot experiments, such readings were excluded in order that more frequent readings of the forehead skin conductivity could be taken, thus giving more exact information regarding the onset of sweating on the forehead.

It was also decided to arrange for longer pre and post experimental periods in order to enable the subjects initially to acclimatise themselves to the atmosphere in the room and finally to reach a reasonably constant physiological state after the working period.

Method

(a) The Assessment of Room Climate

The build-up and decay of temperature and humidity as a result of the gas boiler being lit for approximately a 90 minute period was measured at 3 levels in positions II and at the 4 ft. level in position I (Fig. 2.1) making 4 points in all. The following notation has been used in order to identify them:-

I_2	=	Position I.	4 ft. level.
II_1	=	Position II.	6 ft. 6 ins. level.
II_2	=	Position II.	4 ft. level.
II_3	=	Position II.	6 ins. level.

For this purpose 32 gauge copper constantan thermocouples were attached to the wet and dry bulbs of suspended whirling hygrometers as described in Chapters 1 and 2.

Each subject performed the prescribed task of washing for a family of four on two separate occasions. On the first occasion she was at liberty to open hoppers, casement windows and the door as she herself saw fit in order to maintain a comfortable working atmosphere. However, on the second occasion the subject was strictly limited in this respect, the right hand hopper only being opened.

The subjects were requested to restrict their use of the gas wash boiler to approximately 90 minutes and in all cases within a few minutes they found this period quite adequate.

Physical measurements were carried out at quarter-hourly periods from T = 30 to T = 270 and subsequently every half-an-hour until T = 330 minutes.

The actual experiments were arranged according to the following table:

TABLE 4.1

Days	Subject washing	Control Subject	Ventilation arrangements.
1	B	A	) arranged by
2	A	B	) subject.
3	B	C	) R.H. Hopper
4	A	B	) open only.
5	C	E*	Arranged by subject
6	C	F*	R.H.Hopper only open
7	D	C	Arranged by subject
8	D	C	R.H.Hopper only open.

* These control subjects had to be obtained at short notice to deputise for Subject D.

Anthropometric Data of the Working Subjects.

SUBJECT	HEIGHT	WEIGHT	AGE
A	5 ft. 1½ in.	8 st. 12 lb.	37
B	5 ft. 1 in.	8 st. 7 lb.	37
C	5 ft. ½ in.	8 st. 7½ lb.	50
D	5 ft. 2½ in.	7 st. 10 lb.	30

In all, 6 subjects were employed but of these only 4 were actually engaged in the washing operations.

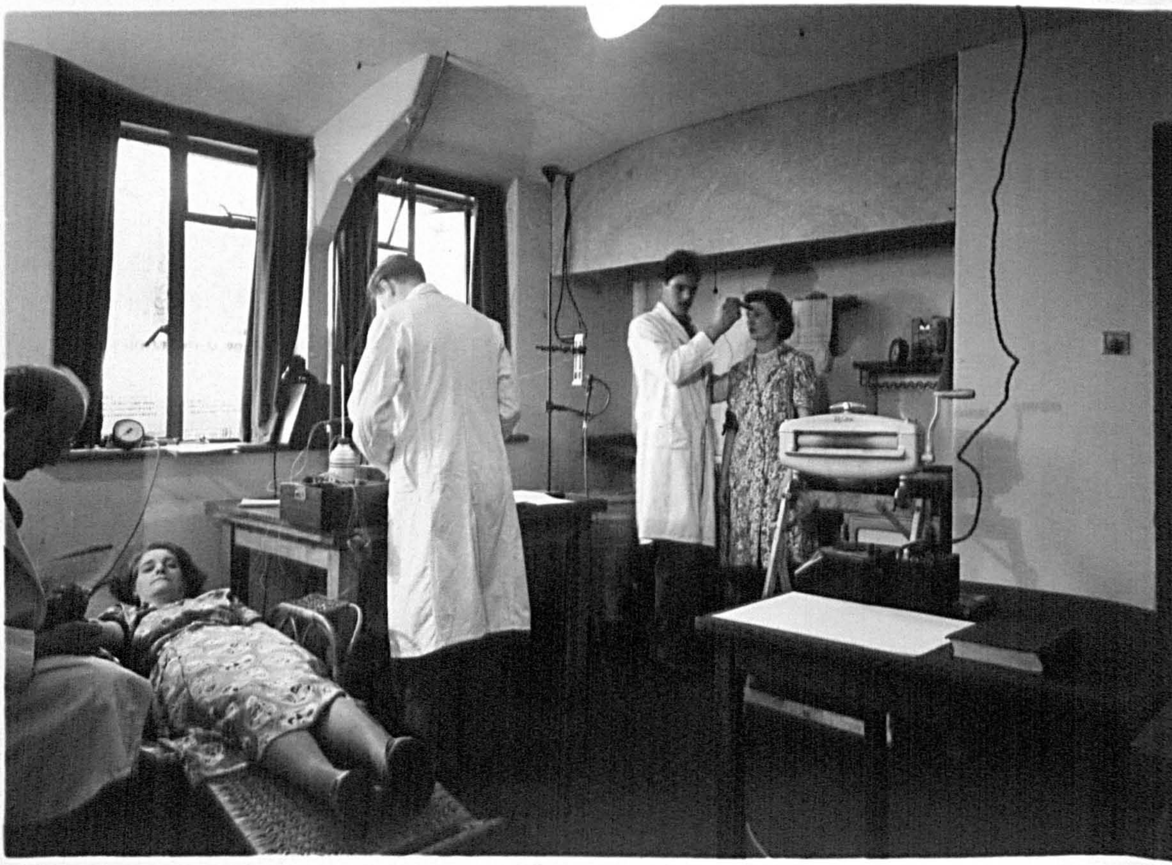


FIG. 4.1

Experimental Procedure. The assessment of Crampton Index, Room Climate and Forehead Skin Conductivity.

Three observers were necessary to take the required data in the room and the experimental arrangement can clearly be seen by studying Fig. 4.1. On the left the control subjects' pulse rate and systolic blood pressure, whilst in a supine position are being measured in order that a value for her Crampton Index can be computed. The observer in the centre is reading the potentiometer, the readings of which give values for the wet and dry bulb temperatures at the 4 positions already described. The third observer is assessing a measure of the forehead skin conductivity of the subject in the working space from a reading of the galvanometer shown on the small table on the right. Also from this photograph the relative positions of the casement windows, hoppers, gas wash boiler and sink are easily gauged.

<u>Assessment of the physiological state.</u>

The pilot experiments had indicated that of the various observations made, only four seemed likely to yield useful information, namely, blood pressure, pulse rate, skin conductivity and subjective thermal sensations. The purpose of the observations on blood pressure and pulse rate was to obtain values for changes in the Crampton Index.

As already indicated the Crampton Index is related to the vaso-motor tone of the subject as it is derived from the changes in pulse rate and increase or decrease in systolic blood pressure on rising from a prone to a standing position. For the evaluation of the Crampton Index the following readings were taken:-

Systolic blood pressure and pulse rate

(a) at rest in the prone position, lying on a couch

(b) after standing for 2 minutes in an erect position.

Readings were taken until two consecutive ones agreed. The skin conductivity was measured over ~~on~~ the centre of the forehead, this position being chosen because of the following considerations:-

1. The forehead skin overlies little muscle.
2. Previous experiments had shown that sweating was more constant in this region.

The relative lack of muscle tends to eliminate variations in conductivity due to variations in blood flow through the underlying muscle due to the performance of muscular work.

A diagram of the apparatus used for the assessment ~~of~~ of skin conductivity is shown in Fig. 3.4 and the description of the apparatus is given on p.66.

The experimental time was divided up into three periods:-

(1) A period of rest and acclimatisation in the experimental room (30 minutes).

(2) A period of work covering the subjects' own particular washing routine. (approximately 4 hours).

(3) A period of 1 hour, the "necessary stage" during which the subject remained at rest in the experimental room.

These experiments differed from those previously carried out in the following respects:-

1. A control, resting, sitting subject was present in the experimental room in position II.

2. Systolic blood pressure and pulse rate readings were taken every 20 minutes for the control subject.

3. Whereas readings for the evaluation of the Crampton Index were originally taken at the end of a particular phase in the washing routine, they were now taken every half-hour.

The skin conductivity was measured on the average every 10 minutes throughout the whole of the experiment. When, however, there was any indication of a great change in the skin conductivity, readings were taken every 5 minutes. At the same time as the conductivity measurements were taken, the subject indicated her subjective sensations of heat, moisture and freshness. A list of these thermal sensations and their appropriate numerical equivalent indices were easily accessible to the subject. The skin conductivity readings and her sensations were taken whilst the subject was in her working space, obviating any error that may have occurred by passing from one part of the room to another. The control subject remained in the working room for the complete experimental period save for the occasions when meals were taken in an adjoining room.

The period prior to the experiment proper was included in order that the subject might familiarise herself with the surroundings and the experience of the various observations.

The washing technique varied slightly from subject to subject. However, a careful study was made of each subject's procedure and to preserve uniformity of activity on the second days, a timetable was given to the subject with instructions to adhere to it as closely as possible. The actual amount of clothes washed varied from subject to subject but each subject did the same amount on the two days. Therefore, the only variable entering the experiments was the difference in the climatic changes on the two days. It was the effect of this difference on the changes in physiological and subjective reactions of the subjects which was to be studied.

Results

Crampton Index and changes in Summated Sensations related to changes in the room climate.

These experiments were carefully controlled, although only carried out on a small number of subjects. The findings clearly indicated that the Crampton Index followed the same general trend of change on both days but was significantly lower on the second day when the subject was working in a warmer and more humid atmosphere which caused greater thermal stress, as indicated by her subjective sensations of heat, moisture and freshness. This was shown to be the case for all the four subjects whose reactions were observed.

The increases in subjective sensations of warmth closely followed the increases in the W.B. temperature as might be expected; moreover, decreases in the Crampton Index corresponded with increases in the subjective sensations of thermal discomfort. Minimum values for the Crampton Index were seen to approximate to maximum wet bulb temperatures at the 4 ft. level in the working space.

During the pre-lunch period in which exercise, in the form of washing and scrubbing was carried out, a marked lowering of the Crampton Index was observed. Furthermore, the fall in the value

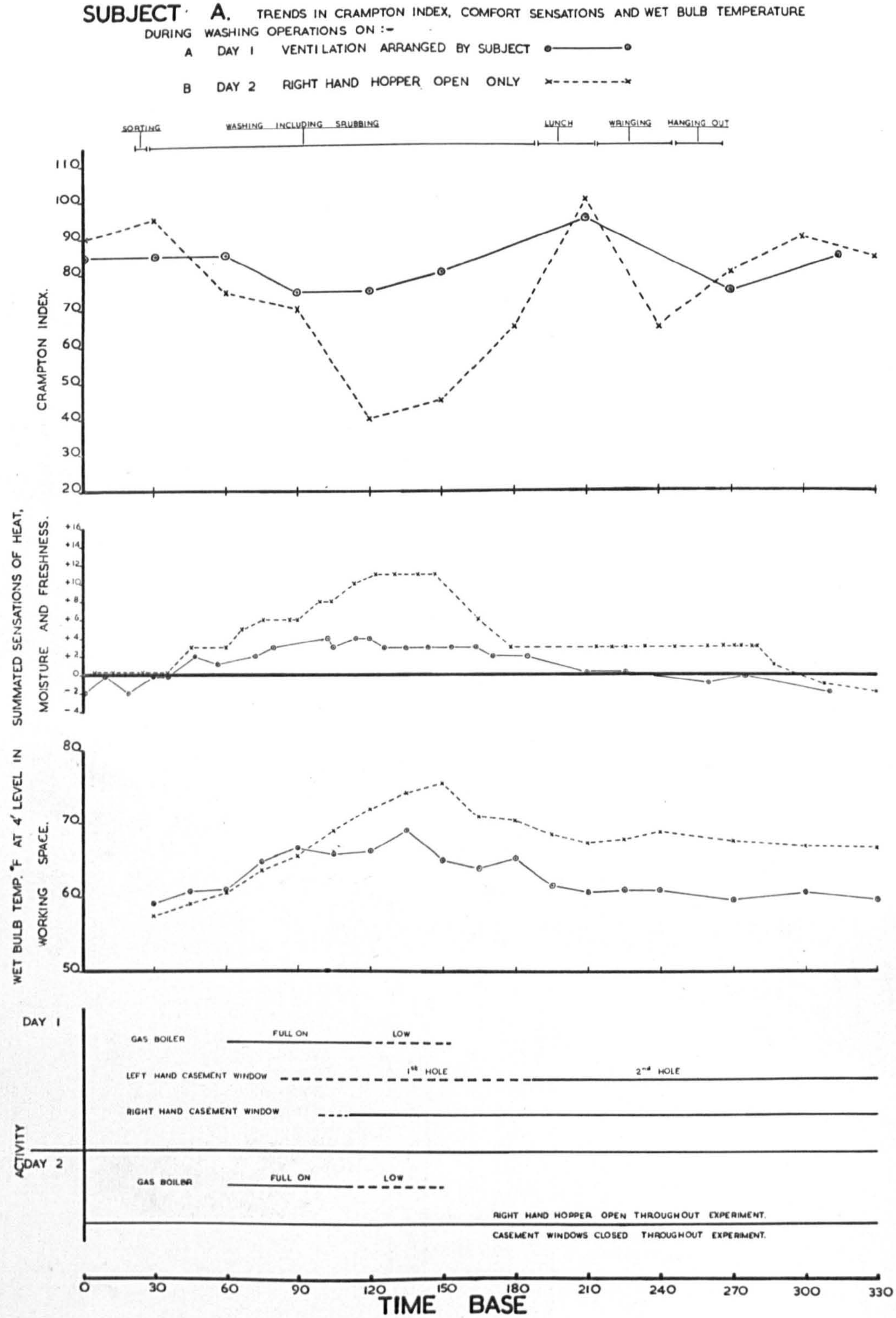

SUBJECT A. TRENDS IN CRAMPTON INDEX, COMFORT SENSATIONS AND WET BULB TEMPERATURE
DURING WASHING OPERATIONS ON :-
A DAY 1 VENTILATION ARRANGED BY SUBJECT
B DAY 2 RIGHT HAND HOPPER OPEN ONLY
SORTING
WASHING INCLUDING SRUBBING
LUNCH
WRINGING
HANGING OUT
CRAMPTON INDEX.
SUMMATED SENSATIONS OF HEAT, MOISTURE AND FRESHNESS.
WET BULB TEMP. °F AT 4' LEVEL IN WORKING SPACE.
ACTIVITY
DAY 1
GAS BOILER
FULL ON
LOW
LEFT HAND CASEMENT WINDOW
1st HOLE
2nd HOLE
RIGHT HAND CASEMENT WINDOW
DAY 2
GAS BOILER
FULL ON
LOW
RIGHT HAND HOPPER OPEN THROUGHOUT EXPERIMENT.
CASEMENT WINDOWS CLOSED THROUGHOUT EXPERIMENT.
TIME BASE

FIG. 4.2

of the index was more marked on those days when the ventilation control was limited and caused a greater rise in the W.B. temperature.

Subjects A, B and C had lunch in an adjoining room maintained at D.B., 65°F., R.H., 50%. During this period their Crampton Indices showed a distinct rise. This increase was less marked however on those days when the pre-lunch thermal stress was greater, except in the case of Subject A whose Crampton Index at this time exceeded the resting value on both occasions.

Subject D took her lunch in the same experimental room. The recovery, in respect of the Crampton Index was much less marked than in the cases of subjects A, B and C.

Further activity after lunch, mainly rinsing of boiled articles, wringing and hanging out, also caused a decrease in the Crampton Index but not so marked as that found during the pre-lunch period when the room temperature was higher. The after lunch activity was not so exacting and the differences in the Crampton Index decreases on the two days under comparison were not so great. The differences in the environmental temperatures on the two days after the gas wash boiler had been turned off were very much less than during the working period. The maximum difference observed in the W.B. readings were 4.0°F. within the 60°F. to 70°F. range.

The Crampton Index reached its minimum values during the period of greatest stress, approximating at the middle of the

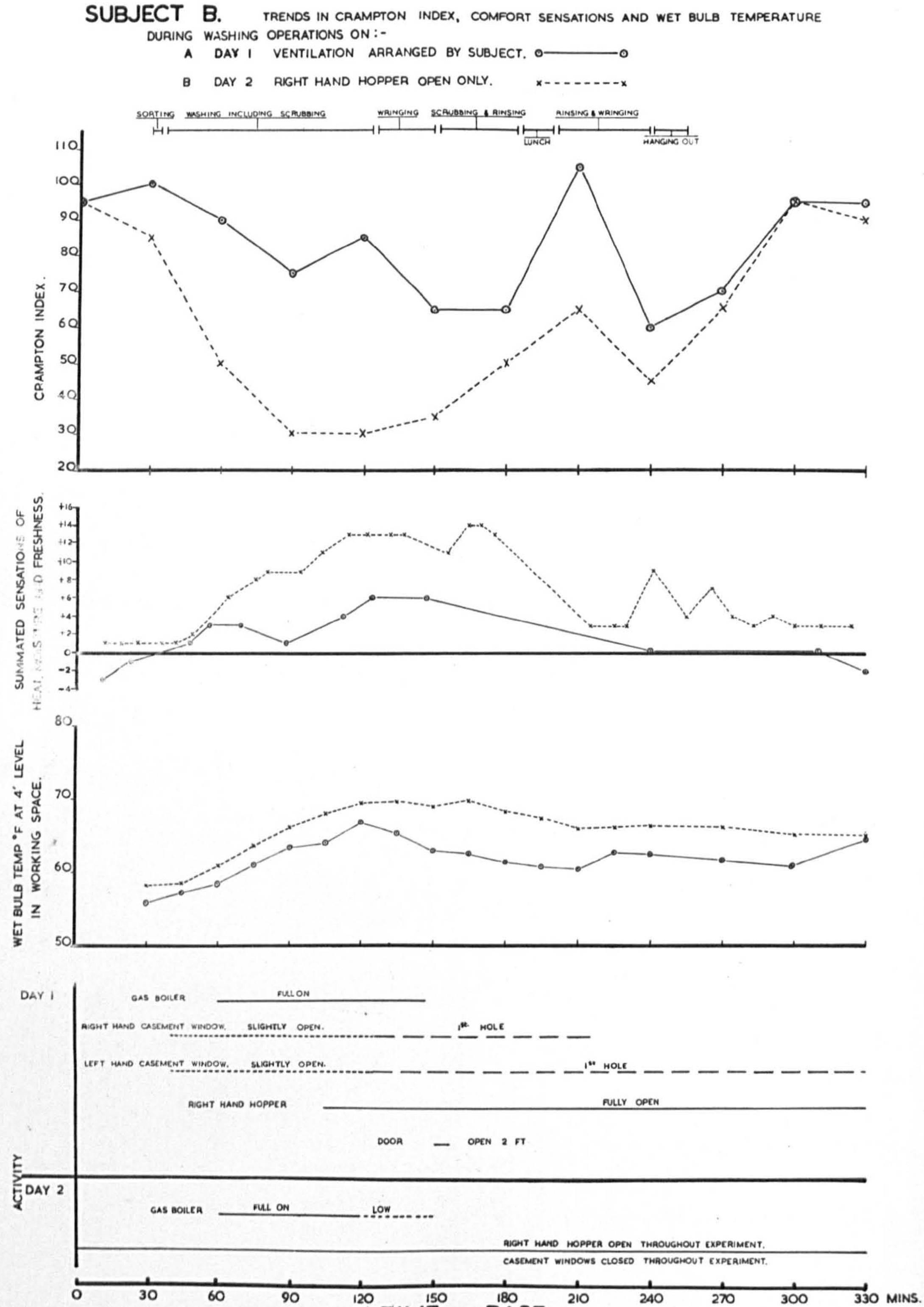

SUBJECT B. TRENDS IN CRAMPTON INDEX, COMFORT SENSATIONS AND WET BULB TEMPERATURE DURING WASHING OPERATIONS ON:-
A DAY 1 VENTILATION ARRANGED BY SUBJECT.
B DAY 2 RIGHT HAND HOPPER OPEN ONLY.
SORTING
WASHING INCLUDING SCRUBBING
WRINGING
SCRUBBING & RINSING
LUNCH
RINSING & WRINGING
HANGING OUT
CRAMPTON INDEX.
SUMMATED SENSATIONS OF HEAT, MOISTURE AND FRESHNESS.
WET BULB TEMP °F AT 4' LEVEL IN WORKING SPACE.
DAY 1
GAS BOILER
FULL ON
RIGHT HAND CASEMENT WINDOW. SLIGHTLY OPEN.
1st HOLE
LEFT HAND CASEMENT WINDOW. SLIGHTLY OPEN.
1st HOLE
RIGHT HAND HOPPER
FULLY OPEN
DOOR
OPEN 2 FT
ACTIVITY
DAY 2
GAS BOILER
FULL ON
LOW
RIGHT HAND HOPPER OPEN THROUGHOUT EXPERIMENT.
CASEMENT WINDOWS CLOSED THROUGHOUT EXPERIMENT.
0
30
60
90
120
150
180
210
240
270
300
330 MINS.
TIME BASE

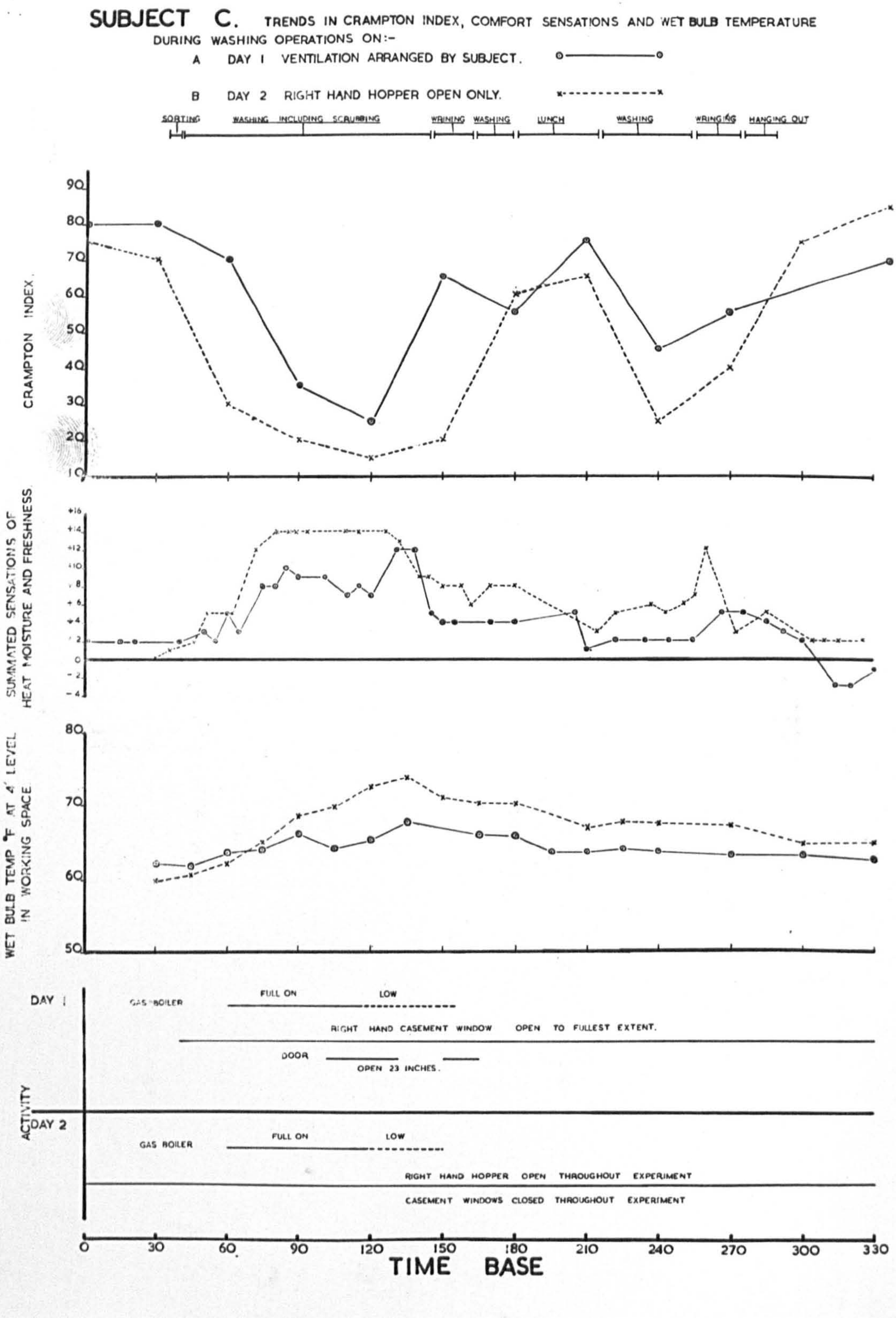
FIG. 4.3

washing period whilst the gas wash boiler was in operation. The minima were reached at approximately the same times on the two days. This was partly due to the effect of work and partly due to the rise in temperature and humidity. See table 4.2 showing minimum values.

It is seen from Table 4.3 that during the last 30 minutes the changes are generally less than during the last hour. In fact the last hour consisted of (a) hanging out the clothes and (b) a period of 30 minutes rest in the experimental room. In other words, recovery took place rapidly on leaving the hot room.

The major part of this change generally speaking took place during (a) which entailed entering an adjoining corridor where the climatic conditions were different from those in the working room.

The greater change in the Crampton Index can be accounted for by the fact that the W.B. temperatures and the R.H's. were considerably lower in the corridor than in the room. The control subjects did not show these marked variations in the last 40 minutes. The changes were randomised between 20 and -15 there being no apparent differentiations between days 1 and 2.



SUBJECT C. TRENDS IN CRAMPTON INDEX, COMFORT SENSATIONS AND WET BULB TEMPERATURE DURING WASHING OPERATIONS ON:-
A DAY I VENTILATION ARRANGED BY SUBJECT.
B DAY 2 RIGHT HAND HOPPER OPEN ONLY.
SORTING
WASHING INCLUDING SCRUBBING
WRINING
WASHING
LUNCH
WASHING
WRINGING
HANGING OUT
CRAMPTON INDEX.
SUMMATED SENSATIONS OF HEAT MOISTURE AND FRESHNESS.
WET BULB TEMP °F. AT 4' LEVEL IN WORKING SPACE.
ACTIVITY
DAY I
GAS BOILER
FULL ON
LOW
RIGHT HAND CASEMENT WINDOW OPEN TO FULLEST EXTENT.
DOOR
OPEN 23 INCHES.
DAY 2
GAS BOILER
FULL ON
LOW
RIGHT HAND HOPPER OPEN THROUGHOUT EXPERIMENT
CASEMENT WINDOWS CLOSED THROUGHOUT EXPERIMENT
0 30 60 90 120 150 180 210 240 270 300 330
TIME BASE

FIG. 4.4.4

TABLE 4.2.

The Crampton Index and Subjective Thermal Sensations in Relation to Room Climate and Experimental Phase.

	DAY 1 (Ventilation arranged by Subject)					DAY 2 (Ventilation controlled)				
	Time (mins.)	°F W.B.	R.H.	Summated Sensations	C.I.	Time (mins.)	°F W.B.	R.H.	Summated Sensations	C.I.
SUBJECT A										
Initial	30	59.2	83%	-2	85	30	57.5	78%	0	90
After scrubbing (min.value)	90	66.8	87%	+4	75	120	71.7	90%	+11	40
After lunch	210	61.0	82%	0	95	210	67.0	89%	+3	100
After wringing	270	60.5	82%	-1	75	240	69.0	90%	+3	65
Final (after 30 minutes rest	330	59.2	78%	-2	85	330	66.0	86%	-2	85
SUBJECT B										
Initial	30	56.0	80%	-1	100	30	58.0	87%	+1	85
After scrubbing (min. value)	150	63.0	87%	+5	65	90	78.6	87%	+11	30
After lunch	210	62.5	82%	0	105	210	66.0	88%	+3	65
After wringing	240	62.5	85%	0	60	240	66.0	87%	+9	45
Final (after 30 minutes rest)	330	60.7	80%	-1	95	330	64.7	87%	+3	90

(Contd.....

SUBJECT D. TRENDS IN CRAMPTON INDEX, COMFORT SENSATIONS AND WET BULB TEMPERATURE DURING WASHING OPERATIONS ON :-

A DAY 1 VENTILATION ARRANGED BY SUBJECT

B DAY 2 RIGHT HAND HOPPER OPEN ONLY

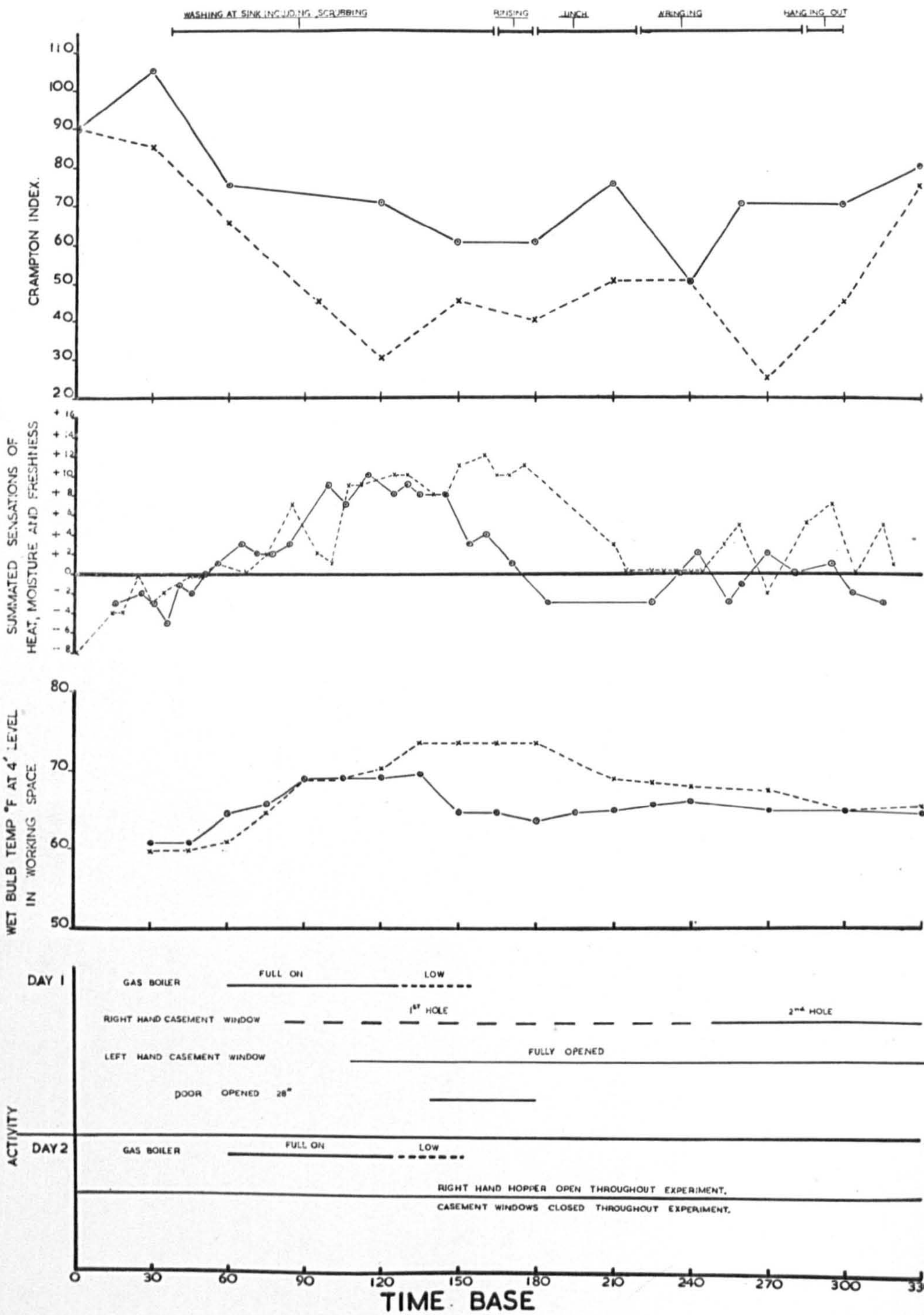


FIG. 4.5

TABLE 4.2. (Contd.)

	DAY 1 (Ventilation arranged by Subject)					DAY 2 (Ventilation controlled)				
	Time (mins.)	°F W.B.	R.H.	Summated Sensations	C.I.	Time (mins.)	°F W.B.	R.H.	Summated Sensations	C.I.
SUBJECT C										
Initial	30	62.1	87%	+2	80	30	59.8	83%	0	75
After scrubbing (min.value)	120	65.3	83%	+7	25	120	72.4	86%	+14	15
After lunch	210	65.6	82%	+5	75	210	67.0	82%	+5	65
After wringing	270	63.0	82%	+5	55	270	67.0	82%	+5	40
Final (after 30 minutes rest)	330	62.4	82%	-1	70	330	64.7	73%	+2	85
SUBJECT D										
Initial	30	60.5	82%	-3	105	30	59.7	89%	-2	85
After scrubbing (min. value)	150	64.2	87%	+8	60	120	70.2	87%	+8	30
After lunch	210	64.5	86%	-3	75	210	66.2	96%	+3	50
After wringing	260	64.5	86%	+2	70	270	67.0	92%	+5	25
Final (after 30 minutes rest)	330	64.2	86%	-3	80	330	65.2	80%	+1	75

TABLE 4.3

Changes in the Subjects' Crampton Index due to:
(a) entering corridor to hang out washed articles,
(b) final 30 minute rest period in the Experimental Room.

		Differences between corridor and Room Climates.			Differences in Crampton Index after hanging out clothes in corridor				Changes in the Crampton Index during 30 minute rest period.			
		W.B. °F	D.B. °F	R.H. %	Subjects A	B	C	D	Subjects A	B	C	D
DAY 1	A	4.3	4.4	9.0	+10				+5			
	B	7.9	7.0	9.0		+25				0		
	C	6.0	5.1	15.0			+5**				+10**	
	D	4.6	6.9	-9.0*				0				+10
DAY 2	A	7.0	4.9	13.0	+10				-5			
	B	11.4	7.3	22.0		+35				-5		
	C	5.7	6.7	3.0			+35				+10	
	D	7.8	4.5	18.0				+20				+30

* Raining outside. ** Figures obtained by interpolation.

Negative sign indicates corridor warmer or more humid than Experimental Room.

TABLE 4.4.

% Decreases in Crampton Index for Working Subjects.

	DAY 1	DAY 2	DIFFERENCE
A	11.8	55.5	36.8
B	31.6	68.4	36.8
C	68.7	80.0	11.3
D	33.3	66.6	33.3

Table 4.4 shows that the % decreases in Crampton Index was again greatest on the 2nd Day for all subjects, the % decrease being least in Subject A and greatest in Subject C. The latter was in an older age group, and the Subject said that she felt the work was rather strenuous for her on both occasions.

During the post lunch working period the variations in Crampton indices were solely due to variations in activity since the W.B. temp. (see Figs. 4.2., 4.3., 4.4., 4.5.,) and D.B. temps., showed little decrease. The differences between days can be accounted for by the differences in W.B. temperature and air movement.

The Control subjects.

A comparison of the trends in the Crampton Indices throughout the experimental period has been made. Such a comparison has only been possible when the same subject has acted as control on the two days when the ventilation arrangements have been different. Therefore from Tables 4.1 showing the subjects participating in the experiments on the various days, it can be seen that these comparisons were possible; namely (a) Subject B, Days 2 and 4, (b) Subject C, Days 7 and 3, (c) Subject C, Days 7 and 8.

A table for (a), (b) and (c) has been compiled which illustrates the differences in the trends of their Crampton indices between the two days. Also shown are the initial peak and final values of the W.B. temperatures and the relative humidities at the 4 ft. and 6 inch levels in the space occupied by the control subject, i.e. positions II_2 and II_3, the remote corner. As was often the case the maxima on the two days did not occur at the same experimental time. In such cases both maxima at the different times have been shown together with the corresponding temperatures and humidities at precisely the same time on the other day. The significance of the difference in the trends of the Crampton Index in both cases for (a), (b) and (c) have been tested and the relevant results are to be found under each table.

TABLE 4.5

(a) Subject A, acting as Control. Crampton Index Differences and Differences in the Room Climate on Days 2 and 4.

	DAY 1 R.H. Hopper open only					DAY 2 Ventilation arranged by Subject.					DIFFERENCES Day 2 minus Day 4				
		4' level		6" level			4' level		6" level			4' level		6" level	
(mins.)	C.I.	W.B. °F	R.H.	W.B. °F	R.H.	C.I.	W.B. °F	R.H.	W.B. °F	R.H.	C.I.	W.B. °F	R.H.	W.B. °F	R.H.
0	105					100					-5				
20	105					100					-5				
30		56.2	76	55.6	79		58.1	79	57.1	81.0		+1.9	+3	40.9	+2
40	95					85					-10				
55	80					90					+10				
80	85					95					+10				
100	90					90					0				
125	75					85					+10				
135		75.6	97	64.0	87		67.3	88	62.6	87		-8.3	-9	-1.6	0
140	85					95					+10				
150		76.9	100	64.4	90		65.5	87	62.6	87		-11.4	-13	-1.8	-3
160	80					100					+20				
185	85					85					0				
200	70					105					+35				
220	80					105					+25				
245	70					105					+35				
260	80					100					+20				
280	85					85					0				
305	80					90					+10				
320	75					90					+15				
330		65.3	81	63.0	84		58.1	70	57.6	70		-7.2	-11	-5.4	-14
340						75									

The difference between the mean values of the Crampton Index for the two days = 9.51.
The Standard Error of this difference = 3.266. Hence $t = \frac{9.51}{3.266} = 2.91$; P less than .01

∴ Difference Significant.

TABLE 4.6

(b) Subject C, acting as Control. Crampton Index Differences and Differences in the Room Climate on Days 3 and 7.

Time (mins.)	DAY 1 R.H. Hopper open only					DAY 7 Ventilation arranged by Subject.					DIFFERENCES Day 7 minus Day 3				
		4' level		6" level			4' level		6" level			4' level		6" level	
	C.I.	W.B. °F	R.H.	W.B. °F	R.H.	C.I.	W.B. °F	R.H.	W.B. °F	R.H.	C.I.	W.B. °F	R.H.	W.B. °F	R.H.
0	80					80					0				
20	75					80					+5				
30		57.4	80	56.2	80		59.8	79	59.8	91		+24	-1	+3.6	+11
40	90					95					+5				
65	85					95					+10				
80	80					95					+15				
100	75					90					+15				
105		67.9	87	62.4	88		69.0	96	63.0	87		+1.1	+12	+0.6	-1
120		69.7	87	64.0	89		68.8	88	64.8	87		-0.9	+1	+0.8	-2
125	85					70					-15				
140	85					80					-5				
160	80					95					+15				
185	80					80					0				
210	75					85					+10				
220	85					85					0				
245	85					90					-5				
280	90					85					-5				
305	100					95					-5				
320	100					90					-10				
330		63.8	80	62.6	87		64.4	84	62.6	87		+0.6	+4	0	0

The difference between the mean values of the Crampton Index for the two days = 2.35

The Standard Error of this difference = 2.02. Hence $t = \frac{2.35}{2.02} = 1.16$; P greater than 0.2

∴ Difference not significant.

TABLE 4.7

(c) Subject C acting as Control. Crampton Index Differences and Differences in the Room Climate on Days 7 and 8.

Time (mins.)	DAY 8 R.H. Hopper open only: C.I.	4' level W.B. °F	4' level R.H.	6" level W.B. °F	6" level R.H.	DAY 7 Ventilation arranged by Subject: C.I.	4' level W.B. °F	4' level R.H.	6" level W.B. °F	6" level R.H.	DIFFERENCES Day 7 minus Day 8: C.I.	4' level W.B. °F	4' level R.H.	6" level W.B. °F	6" level R.H.
0	75					80					+5				
20	85					80					-5				
30		58.5	79	57.1	82		59.8	79	59.8	91		+1.3	0	+2.7	+9
40						95					+10				
65	85					95					+10				
80	85					95					+10				
100	85					90					+5				
105		68.8	82.0	63.6	97		69.0	96	63.0	87		+0.2	+14	-0.6	-10
125	80					70					-10				
140	85					80					-5				
150		73.3	95	65.3	88		64.2	88	63.6	87		-9.1	-7	-1.7	-1
160	75					95					+20				
185	85					80					-5				
210	75					85					+10				
220	75					85					+10				
245	85					95					+10				
260	85					90					+5				
280	75					85					+10				
305	85					95					+10				
320	85					90					+5				
330		64.4	84	64.0	94		64.4	84	62.6	87		0	0	-1.4	-7

The difference between the mean values of the Crampton Index for the two days = 5.79.
The Standard Error of this difference = 2.20. Hence $t = \frac{5.79}{2.20} = 2.63$; P less than .02

$\therefore$ Difference significant.

These results show us that in two out of three such comparisons the trends in the control subjects' Crampton indices are significantly different. In addition, we must draw attention to the differences in the W.B. temperatures at the 4 ft. level in the appropriate position (Position II_2).

For the comparison between Days 2 and 4 the mean of the differences of eighteen such wet bulb temperature readings throughout the experimental period was 4.84°F. With a standard error of 0.93°F. Such a difference is significant. Furthermore, the corresponding figures for the experiments on Days 7 and 8 (mean of 17 readings) were 2.18°F with a standard error of 0.94°F. Again significant.

The most interesting result however, is obtained when a similar comparison is made between experiments on Days 3 and 7. In this case, as already shown, the differences in the Crampton indices are not significant. Furthermore the mean of the differences of the eighteen wet bulb temperature readings yields the figure 0.52°F. with the corresponding standard error of 0.57°F. Such a difference is clearly not significant ($t = 0.91$).

Thus we can conclude that in the three comparisons made for subjects in a position of rest throughout the experimental period significant differences in their Crampton indices were obtained only when the differences in the wet bulb temperatures at the 4 ft. level at position II_2 were significant.

Skin Conductivity and Summated Sensations of Heat, Moisture and Freshness.

(a) Working Subjects.

The following tables have been prepared to show the times of occurence of maximum temperatures, summated sensations of heat, moisture and freshness, together with values for the skin conductivity of the subjects.

TABLE 4.8

Subjective Thermal Sensations & Skin Conductivity in Relation to Room Climate.

Time	Skin Conductivity $ohms^{-1} \times 10^{-6}$	Summated Sensations	W.B. °F	D.B. °F	
		SUBJECT A			
47	3.66	2	60.7	63.6)	Day 1
103	1.36	4	65.5	68.2)	
135	2.49	3	68.8	70.1)	
122	73.7	11	71.8	74.0)	Day 2
147	100.0	11	75.2	76.5)	
		SUBJECT B			
47	3.82	1	57.4	60.7)	Day 1
124	2.33	6	65.8	68.4)	
135	0.96	6	68.8	70.1)	
165	59.0	14	69.7	71.8)	Day 2
174	69.4	13	68.2	70.1)	
		SUBJECT C			
131	900.0	12	67.7	69.7)	Day 1
135	980.0	7	67.7	69.7)	
150	857.0	4	67.9	72.0)	
115	780.0	14	72.4	75.6)	Day 2
135	536.0	13	73.8	75.2)	
		SUBJECT D			
105	7.3	7	68.8	73.3)	Day 1
115	1.0	10	68.8	72.0)	
135	12.7	8	69.3	72.4)	
150	27.6	11	73.3	76.4)	Day 2
160	26.0	12	73.3	74.2)	

Generally speaking, the skin conductivity values showed greater increases on Day 2 than on Day 1, but Subject C showed very little difference in this respect. It should be noted that the Crampton Index for this subject fell steeply during the scrubbing period on the first day approximately to the minimum value reached on the second day. It was possible that the physical effort involved was almost maximal on the two days and this would account for the only slight differences observed in the skin conductivity. Furthermore, the maximum W.B. differences were only 6°F. during this period. It must be remembered too, that she was an older subject and the normal powers of adaption were consequently somewhat reduced.

It is seen that small increases in W.B. temperature in the range 65°F - 75°F. caused marked increases in sweating on Day 2, which was not proportionately equal for all subjects. This can be accounted for in part by the fact that the air movement, by virtue of the through ventilation of the working space was greater on the first day, (approximately 200 ft/min. compared with 10 ft/min.). The controlled experiments described in Chapter 5, p.143 indicate that sweating as a result ot exercise, where air movement was approximately 100 ft/min. does not show marked increases until a W.B. temperature of approximately 75°F. is reached. The subjects in these experiments were young men and women in the age group 20-30 years. Returning to the experiments under discussion, the observations indicated that the skin conductivity was rapidly affected by the amount of muscular work performed, this being particularly marked on Day 2. The sudden increases in skin conductivity were associated with the appearance of visible perspiration.

These sudden increases usually occurred when the value reached 30×10^{-6} ohms^{-1}. This appeared to be a critical value.

In all cases the summated sensations were greater on Day 2 than Day 1. The maxima were associated with maximum muscular activity and skin conductivity and maximum values of W.B. temperatures. However, it should be pointed out that there is a slight time lag between the occurrence of maximum sensations and maximum sweating, the former preceding the latter by about 20 minutes for each subject. The summated sensations were stable during the pre-experimental period, rising during the initial washing period to a maximum, falling during the lunch interval followed by smaller rises during the later periods of activity.

It will be observed that changes in skin conductivity were closely allied to changes in summated sensations. In fact, neglecting the above-mentioned time lage the following correlation coefficients between the two variables have been found:-

Subject A:	$0.799 \pm .095$
Subject B:	0.723 ± 0.116
Subject C:	0.555 ± 0.168

The times of onset of sweating as indicated by the appearance of visible sweat coincident with marked increases in skin conductivity were:-

	Day 1	Day 2.
Subject A:	-	120 minutes.
Subject B:	-	150 minutes.
Subject C:	90 minutes.	90 minutes.

If 35 minutes be substracted from these values they are then in terms of the actual time that elapsed between the commencement of washing and the appearance of visible sweat.

(b) Control Subjects.

TABLE 4.9

Skin Conductivity Ranges: Control Subjects.

Days	Subject	Ventilation arrangements	Variations in Skin Conductivity (ohms^{-1} x 10^{-6})	Max. W.B. temp. in Pos. II2 (4 ft. level)
1	A	by subject	0.16 - 6.5	66.2
2	B	by subject	0.83 - 13.9	67.3
3	C	Fixed	1.66 - 9.5	68.8
4	D	Fixed	0.66 - 11.45	76.9
5	E	by subject	0.16 - 2.98	68.6
6	F	Fixed	1.66 - 16.7	76.4
7	C	by subject	0.99 - 5.15	69.0
8	C	Fixed	0.16 - 2.99	73.3

It will be seen that all the values are considerably less than the limiting values and indeed it was noted that at no time did any of the control subjects show any visible changes in sweating.

Such values for skin conductivity are based on very small galvanometer deflections, which consequently could not be read with great accuracy. Each calculated value is subject to an error of $\pm$ 0.34 x 10^{-6} ohms^{-1} due to possible errors in the reading of a small galvanometer deflection on its lowest range.

The apparatus has not been designed to measure absolute values of skin conductivity but only to illustrate gross changes associated with changes in environmental conditions or the performance of muscular work.

Climatic Conditions and Vitiation of the Room Air.

High humidities cause condensation to occur on surfaces which have temperatures less than the dew point of the room air. Such condensation can be a source of serious damage to floors, paint, wallpapers and furnishings. Therefore the problem is to arrange for maximum ventilation of the room consistant with maintaining a comfortable working atmosphere, i.e. without the creation of undesirable draughts. In the experiments under consideration, two different modes of ventilation were employed. One in which the right hand hopper alone was opened. Previous experiments had shown that such an arrangement gives rise to an overall air change of 2.0 to 3.5 room air changes per hour. The second method of ventilation was not fixed as it was arranged by the subjects. The accurate estimation of the air change brought about by the various hoppers and windows being opened together with the door is very difficult, owing to the limitations of the CO_2 tracer method used. Furthermore, an overall estimate of the airchanges in the room under such conditions would not apply to all parts of it. It was quite apparent that in the working space, the airchange rate exceeded considerably the rate at Position II, the remote corner, because of the through ventilation between the windows and door.

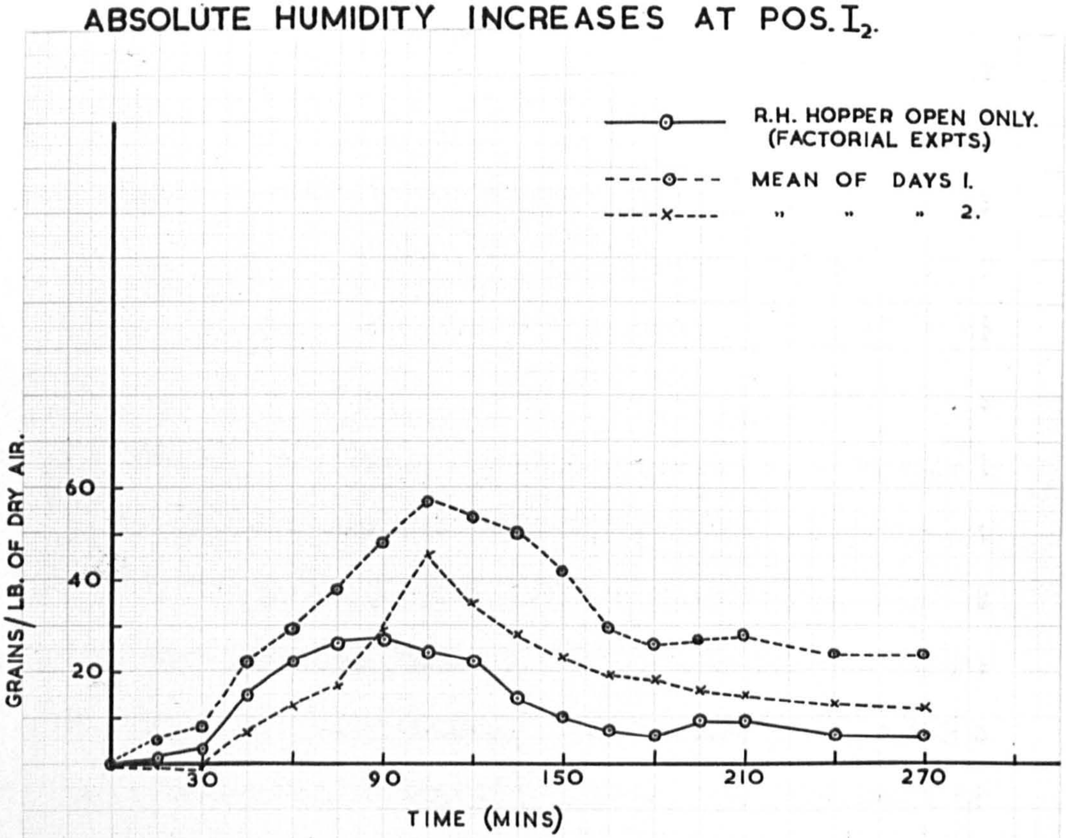

ABSOLUTE HUMIDITY INCREASES AT POS. I_2.
R.H. HOPPER OPEN ONLY. (FACTORIAL EXPTS)
MEAN OF DAYS 1.
" " " 2.
GRAINS/LB. OF DRY AIR.
60
40
20
30
90
150
210
270
TIME (MINS)

FIG. 4.6

However, from the point of view of the vitiation of the air, resulting from gas combustion and the presence of five persons within the room, the CO_2 concentration never exceeded 0.29% at mid-level and 0.26% at burner level near the gas wash boiler on those days when the right hand hopper only was opened. Any presence of CO in the room could not be detected by the CO indicator Mk III (no. 1); such an instrument can readily detect the presence of CO to 1 part in 100,000 (0.001%). The upper physiologically safe limit is 0.01% for CO. No estimation of any other products of combustion such as SO_2, SO_3, NO_2 or CH_2O was made; only one subject detected any smell to be associated with the combustion of coal gas in the wash boiler, but she thought it by no means objectionable. Thus we can say that throughout the series of experiments the air change rates were well within the limit necessary to avoid any toxic effects from the vitiated air. It should be remembered that this gas appliance had no direct lead to the external air with the result that the combustion products were free to be liberated into the room and accumulate in the working space in the vicinity of the boiler unless controlled by a suitable method of ventilation.

__Absolute Humidity.__

Fig. 4.6 is a graph illustrating the build-up and decay of absolute humidity in grains per pound of dry air at the working space during the experimental period. The 3 different conditions shown are:-

1. R.H. hopper open only. Mean value of the four experiments.
2. Subject deciding ventilation. - do. -

3. R.H. Hopper open only. Gas boiler lit but no washing performed. The data was obtained from previous experiments and again each figure is the mean of four values.

The graphs show the increases in absolute humidity above the initial value recorded at the commencement of each experiment, and the effects of the two different ventilation rates can be seen. The increase was less for Day 1 than it was for Day 2 (27 as compared with 57 grains per lb. of dry air).

It is interesting to compare conditions 1 and 3 where the difference between them was that washing was performed in 1 but not in 3. The increase in the absolute humidity due to the contribution from washing, rinsing and wringing of the garments can be seen.

The Wet Bulb Temperatures.

Mention has already been made (p.107) of the significance of the W.B. temperature at the location of the seated subject. It has been observed that for this subject the mean Crampton index only differed significantly on those days when the W.B. temperatures were significantly different.

The increase in W.B. temperature in the working space was markedly different for the two different ventilation rates and is clearly indicated on the graphs illustrating trends in Crampton index, summated sensations and W.B. temperature. The following table giving the initial peak and final values of the temperature at Pos. II_2 shows the effect of an increased ventilation rate on the maintenance of a lower W.B. temperature.

TABLE 4.10

W.B. Temperature Increases at Position I_2 (Working space).

	Initial °F	Peak °F	Final °F	
Subject A	59.1	68.8	59.3	Vent. arranged by subject.
	57.4	75.2	66.2	R.H. Hopper only.
Subject B	56.0	66.9	60.7	Vent. arranged by subject.
	58.1	69.7	64.8	R.H. Hopper only.
Subject C	62.1	67.9	62.4	Vent. arranged by subject.
	59.8	73.8	64.7	R.H. Hopper only.
Subject D	60.7	69.3	64.4	Vent. arranged by subject.
	59.8	73.3	65.3	R.H. Hopper only.

The Dry Bulb Temperature

A similar table for D.B. temperature has been drawn up (Table 4.11). Both tables not only illustrate lower peak values for both wet and dry bulb temperatures on those days when the ventilation was arranged by the subjects but also the important fact that also on those days the difference between Final and Initial temperatures was less, i.e. initial conditions of temperature and humidity were more closely approached on Day 1 than on Day 2.

TABLE 4.11

D.B. Temperature Increases at Position I_2 (Working Space).

	Initial °F	Peak °F	Final °F	
Subject A	62.4	70.1	64.0	Vent. arranged by subject.
	61.7	75.8	69.3	R.H. Hopper only
Subject B	59.6	69.7	64.4	Vent. arranged by subject.
	60.7	72.4	67.7	R.H. Hopper only
Subject C	64.8	72.0	66.0	Vent. arranged by subject.
	62.8	75.6	70.7	R.H. Hopper only
Subject D	64.4	73.3	67.1	Vent. arranged by subject.
	61.7	76.4	68.8	R.H. Hopper only.

Temperature gradient at Position II_2.

In rooms used for continuous occupation it has been recommended that the dry bulb air temperature at foot level should be not more than 5°F lower than at 5' 0" level.

The following table shows differences in D.B. temperatures at the 6'6" and 6" levels at Pos. II at three phases of each experiment.

TABLE 4.12

D.B. Temperature gradients at POS. II.
(the remote corner of room).

Control Subject	Inital °F	Peak °F	Final °F	
A	0.7	7.8	1.5	Vent. arranged by subject
C	1.6	7.6	2.8	R.H. Hopper only
B	1.9	5.5	0.9	Vent. arranged by subject
B	1.9	14.0	3.3	R.H. Hopper only
E	2.5	4.5	1.7	Vent. arranged by subject
F	2.1	8.9	-	R.H. Hopper only
C	2.8	7.0	3.5	Vent. arranged by subject.
C	2.7	8.1	3.5	R.H. Hopper only

The table shows that the temperature gradients were less on those days when the ventilation arrangements were made by the working subject. The mean value for days 1 being 6.2°F and for days II 9.6°F. Assuming a linear increase of temperature from the floor level upwards, the corresponding figures for the difference in temperature between the floor or foot level and the 5' 0" level would be 5.1°F and 8.0°F respectively.

Discussion

Crampton states that most people in normal health show an index of between 60 and 80. Below 50 he holds to be abnormal; a high index in a person obviously in poor health is abnormal. An index below zero is conclusive evidence of impaired circulation, or toxaemia or severe physical disturbance.

Experience has shown that minor changes in the index are not significant since there is an error of plus or minus 5 mm. Hg. in the measurement of blood pressure which can result in a maximal error of 10 points in the assessment of the index. It may be concluded, therefore, that trends in the index are more significant than separate determinations. Healthy people show widely divergent values for the index, consequently it is individual <u>changes</u> in the index which must be investigated. There are minor daily variations for a particular subject, e.g. of the order of 5 for the Crampton Index. Crampton was of the opinion that a low index was associated with diminished powers of adaptation of the circulation and impaired physical efficiency. It is worthy of note that the Crampton Index can be readily determined and may be employed in field studies where the amount of equipment to be used must be a minimum and when it is desirable to reduce interference with the subjects' routine also to a minimum.

The results have shown that the Crampton Index was significantly lower on the 2nd day of operation when the air change rate was purposely restricted. That this is due to the environmental conditions is shown by the fact that:

(a) The amount of work done on the two days was the same.

(b) The initial resting values of the index were the same.

(c) Their general trends were the same.

Crampton, in the evolution of his index, considered that constriction of the splanchnic vessels contributed the larger part of the peripheral resistance, but in the experiments there was considerable dilatation of the skin vessels as indicated by the increased rate of sweating. Such a dilatation would detract from the value of the peripheral resistance and consequently give a lower value for the Crampton Index. Crampton originally designed his index for use in temperate climatic conditions and the experiments described in Chapter 5 were to test the validity of the Index under conditions of increased temperature and humidity.

It has been shown by the New York State Ventilation Commission (1923)[38] that variations in air movement cause significant differences in the index; the greater the air movement the higher the index. Since the air movement on Day 1 was greater than on Day 2, this was undoubtedly a factor of significance, due to the increased cooling effect of the air on the body.

The increase in wet bulb temperature was greater on Day 2 which impeded the evaporation of sweat and consequently the blood flow through the skin was greater in an effort to maintain thermal equilibrium, i.e. thermal stress was greater on Day 2 when the Crampton Index showed a greater fall. Thermal stess even at rest becomes evident when the wet bulb temperature approaches 80°F.

The degree of activity of the subject has a bearing on the value of the index; the greater the activity the lower the index in subjects of the type used in the present study. Since the activity of the subjects was the same on the two days, the differences in the indices are considered to be due to the marked differences in the environmental conditions. A marked fall resulting in low values is considered to be significant sinse the subjects complained of fatigue at precisely those times when the index was found to be low in relation to the resting initial value.

The Crampton Index for those subjects who took lunch in an adjoining room, rose more steeply than for those subjects who remained in the experimental room during this period. This can be attributed to the better climatic conditions (65°F. D.B., 50% R.H.), prevailing in the adjoining room since duration of the lunch period and type of meal were essentially the same.

The experiments have shown generally that a high degree of correlation exists between summated sensations and skin conductivity as measured. It would appear that the rapid onset of sweating as indicated by the sudden increase of skin conductivity and the simultaneous appearance of visible sweat did not associate itself with any decrease in the summated sensations. It has been observed that a plateau of the maximum value of skin conductivity usually occurs during the period of greatest activity. The increases and decreases in skin conductivity are rapid, indicating the degree of physiological adaptation to the thermal stress of the moment.

The experiments have shown that in general the changes in skin conductivity were greatest on Day 2. This was associated with greater changes in wet bulb temperature. However, the percentage changes in wet bulb temperatures were relatively small compared with percentage changes in skin conductivity. From this it would seem that the W.B. temperature is of the utmost importance when the thermal stress of the subject is to be considered. It appears that with the degree of activity under consideration a W.B. temperature of approximately 65°F

(R.H. 80%) is associated with the commencement of a positive increase in the subjective sensations. The summated sensations and skin conductivity depend in part upon the degree of activity but it is significant that the maximum values were obtained towards the end of the period of maximum activity.

The scale (p. 63) used for subjective sensations was originally designed to be used for subjects at rest or during the performance of light sedentary work. Consequently, the upper regions were reached at relatively lower temperatures and in some cases eveh an extension of the scale was indicated. Furthermore, the subjects were instructed that maximum values on the heat and moisture scales were to be interpreted as being those relevant to an environment inducing maximum discomfort, which indeed they would be if the subject was at rest.

In addition it might be pointed out that a certain amount of practice in the use of the moisture scale was indicated. For the untrained observer the assessment of the sensation of moisture is not easy. However, in these experiments, since frequent observations were carried out, the subjects soon became conversant with this scale and consequently the records can be considered reliable. The freshness scale, ranging from 'very fresh' to 'very stuffy', is only sub-divided into five grades. Whereas the negative (or fresh) grades were adequate, the positive (or stuffy) grades were coarse and most subjects indicated that the positive values should be sub-divided in order to give a value consistent with their subjective feeling.

SUMMARY

1. Following a pilot study a series of full scale user-test experiments has been carried out to assess the changes in some physiological reactions associated with changes in room climate during the performance of domestic washing by four different experienced housewives who acted as subjects.

2. The physiological changes studied on the working subject and on a seated, control subject were:-

(a) Changes in vaso-motor tone as indicated by the changes in the Crampton Index of each subject.

(b) Sweating as indicated by changes in skin conductivity.

(c) Subjective sensations of heat, moisture and freshness.

3. The room climate was determined by observations of dry bulb temperatures and relative humidity at four points in the room. These observations were made by thermocouples attached to the wet and dry bulbs of suspended hygrometers ventilated as required.

4. A study of the procedure of each subject was made and the same routine was carried out on the two days.

5. Each subject performed her task under two different sets of conditions, namely (a) ventilation arranged by subject. Day 1. (b) ventilation restricted to the use of one hopper only. Day 2.

Condition (b) gave rise to an overall air change rate of 2.0 to 3.0 room air changes per hour.

6. The results obtained were:-

(a) The Crampton Index, the skin conductivity, and the summated sensations of heat, moisture and freshness showed marked variation between the two days. Summated sensations and skin conductivity were greater and the Crampton Index was lower on Day 2.

(b) Consistent with (a) was the fact that the ventilation rate being restricted on Day 2, gave rise to greater increases in W.B. and D.B. temperatures in the working space.

CHAPTER V.

Changes in Crampton Index, Subjective Thermal Sensations and Skin Conductivity Related to Changes in Environmental Temperature and Humidity.

Introduction

The results of the pilot experiments, which were confirmed and amplified by the Full-scale user-test experiment described in Chapter III and IV respectively, showed that gross changes in the Crampton Index, Summated Sensations of Heat and Moisture and the skin conductivity were closely linked with thermal stress and discomfort on the part of the subject whilst working in a hot and humid atmosphere.

However, it was necessary to carry out further experiments to ascertain if a quantitative relationship existed between the changes in these physiological reactions and environmental thermal changes. From the findings of such a series of controlled experiments one could then determine whether or not changes in the Crampton Index were valid physiological indications related to thermal stress. Also, the possibilities could be examined for the prediction of changes in these physiological reactions for a subject performing a known fixed amount of work when exposed to known temperature and humidity changes.

Other physiological reactions, e.g. Stone, Tigerstedt and P.P. x P.R. tests have been discussed in Chapter III. It was shown that these tests showed changes which were not consistent with the opinions of the subjects and furthermore, not consistent with the differences in the environmental changes on the two days studied for each working subject. These were indices which could easily be assessed under the conditions arising from the performance of clothes washing in a kitchen or a kitchen living room. Therefore, in a controlled physiological investigation only those reactions which are readily assessable under such conditions can be considered as being of any practical value in this type of investigation.

Finally, the significance of sudden increases in skin conductivity in relation to the time of onset of sweating had to be examined under controlled experimental conditions.

Experimental method

The experiments were carried out entirely in an air conditioned room. The room measured 12 ft. x 9 ft. 6 in. x 7 ft. high with inlet and outlet ducts to provide continuous circulation of the air. The wet bulb and dry bulb temperatures were thermostatically controlled at desired levels. An electric fan was set at one corner to provide air movement. An auxiliary two kilowatt heater was also placed in the room in order that the upper extremes of the temperature ranges considered could be reached. The walls of the room consisted of a double thickness of asbestos board separated by an air space containing sheets of reinforced aluminium foil to provide heat insulation.

Six subjects in all were used, each subject participating in four separate experiments. Two subjects were present in most experiments; a control subject, who remained completely at rest and a working subject who peformed a fixed amount of exercise. Each acted as a resting subject on two occasions and as a working subject on the other two occasions.

Two constant humidity levels were maintained throughout an experiment namely 60% or 80% whilst the temperature was gradually increased from that of normal room air (55°F.-60°F. dry bulb) up to approximately 100°F. dry bulb over a four and a half hour period.

Therefore the four experimental conditions for each of the six subjects were:-

(1)	Resting	Constant R.H. 60%	Temperature gradually increasing.
(2)	Resting	" R.H. 80%	
(3)	Exercising	" R.H. 60%	
(4)	Exercising	" R.H. 80%	

These conditions were chosen for the following reasons:-

(a) Changes in the physiological reactions under consideration resulting from gradual increases in temperature could be studied.

(b) The effect of a fixed amount of exercise on these physiological reactions could be assessed for each subject.

(c) The extent to which the humidity levels affected the onset of sweating on the forehead could be ascertained.

(d) The temperature ranges adequately covered these ranges encountered in the kitchen living room during the User-test experiments.

Routine Experimental Procedure: During the preliminary stage of each experiment the subjects were required to lie resting quietly on a couch in the experimental room for a half an hour period. During this time the temperature and humidity were held constant at this initial level, whilst the lying and standing blood pressures and pulse rates were measured, the forehead skin conductivity was assessed and the subjective sensations of heat, moisture and freshness according to the scale shown on p. 63 were recorded for both subjects. This period was necessary in order that the subjects could attain a state of equilibrium from which subsequent reactions to environmental changes could be assessed.

When the two subjects were present for a particular experiment the control subject remained at rest on a couch throughout the experimental period except of course whilst the standing blood pressures and pulse rates were being observed. The Crampton Index and forehead skin conductivity were recorded every 16 minutes, and subjective thermal sensations were assessed every 8 minutes for this subject.

The working subject performed exercise, which consisted of step climbing for two minutes at 16 minute intervals during a period of approximately 4 hours. Exercise was performed during the time the Crampton Index was being measured for the control subject. The step consisted of a 1 foot rise with an intermediate step at the 6 inch level. The subject placed one foot on this intermediate step both in ascending and descending. The subject ascended thirty times without turning during the two minute period. For this subject the Crampton Index was assessed every 16 minutes, midway between two consecutive periods of exercise. The subjective thermal sensations were recorded at these times and also, together with the forehead skin conductivity immediately before and after exercise.

<u>Environmental Conditions</u>: The physical characteristics of the experimental environment which were measured were as follows:-

(a) Dry Bulb and Wet Bulb temperatures by the whirling psychrometer.

(b) Globe thermometer temperatures.

(c) Air velocities from the cooling times of a 130 - 125°F. glass kata thermometer.

These observations were taken every 8 minutes throughout each experiment and a check was kept on the relative humidity at all times.

Observers: Two observers were present in the experimental room. Mr. J. Brown who collaborated with me in these experiments recorded the pulse rates and blood pressures from which the values of the Crampton Indices were computed

Subjects: All the subjects were fit and healthy medical students in the age group 20 to 30 years. Four were men and two were women.

Clothing worn by the subjects: Each subject wore exactly the same clothing for each of his or her tests. It consisted essentially of a linen or light woollen shirt, linen shorts, socks and light rubber shoes. In the case of Subject No. 1 a woollen skirt and stockings were worn in all experiments. It is possible that this difference in clothing may have, in part, accounted for the different degree of reactions to environmental changes as compared with the other subjects.

Results

I. Changes in the Crampton Index in Relation to Changes in the Physical Environment.

The results obtained from all the six subjects who participated in these controlled experiments showed that increases in the environmental warmth caused marked decreases in the transitory values of the Crampton Index and that the rate of fall was increased when a standard amount of exercise, in the form of step-climbing at a fixed rate, was performed at regular intervals throughout the experimental period.

These decreases in the value of the Crampton Index were highly linearly correlated with the increases in the wet bulb temperature, a purely physical characteristic of the atmosphere and also with the corrected effective temperature over the range considered in the present study.

The effective temperature is a single index evaluated from combinations of temperature, humidity and air movement. This index does not describe a physical characteristic of the air since the formulation of the scale was based on the subjective thermal sensations of a large number of lightly clothed subjects who compared their feelings of warmth in an environment of known conditions to one with still and saturated air. The temperature of the latter environment was regulated until the same feeling of warmth was expressed as in the original environment (Yaglogiou and Miller, 1925)[39]. However, the scale does not make allowance for the effects of radiant heat. Houghton and McDermott (1933)[40] pointed out that a correction should be applied for the effect of cold walls. Bedford (1946)[12] has made an allowance for radiant heat loss or gain by using the globe thermometer reading in place of the air temperature, the scale then being known as the "Corrected Effective Temperature Scale."

The influence of the wet bulb temperature on changes in the Crampton Index was studied because Haldane (1905)[41] pointed out the importance of the temperature shown by the wet bulb thermometer as having an important bearing on subjective thermal sensations and physiological reactions. Furthermore, Houghton and Yaglogiou (1923)[42] have shown that fordew-point temperatures above 61.5°F (at the lower limit of the range of temperature used in the present study), the wet bulb temperature exerts a greater influence on thermal sensations and physiological reactions than does the dry bulb temperature. They also showed, however, that a higher correlation existed between certain reactions, such as loss of weight per hour, increase in body temperature per hour and increase in pulse-rate per hour with effective temperature than with the wet bulb temperature.

The following table gives the values of the correlation coefficients of the Crampton Index with the wet bulb temperature and with the corrected effective temperature calculated for each experiment.

TABLE 5.1

Correlation coefficients of transitory values of the Crampton Index with wet bulb temperature and with corrected effective temperature.

Subject No.	RESTING R.H.60%	RESTING R.H.80%	STEP-CLIMBING. R.H.60%	STEP-CLIMBING. R.H.80%	Crampton Index correlated with:-
1	-0.619 -0.790	-0.917 -0.930	-0.914 -0.860	-0.945 -0.880	Wet bulb temperature Corrected Effective Temp.
2	-0.815 -0.856	-0.901 -0.896	-0.912 -0.947	-0.966 -0.980	W.B. C.E.T.
3	-0.897 -0.919	-0.936 -0.937	-0.965 -0.965	-0.968 -0.990	W.B. C.E.T.
4	-0.969 -0.987	-0.933 -0.941	-0.919 -0.971	-0.933 -0.898	W.B. C.E.T.
5	-0.825 -0.834	-0.930 -0.918	-0.941 -0.955	-0.933 -0.854	W.B. C.E.T.
6	-0.870 -0.912	-0.813 -0.954	-0.945 -0.737	-0.945 -0.947	W.B. C.E.T.

In reference to the above table it may be noted that a numerical value of the Correlation Coefficient greater than 0.455 can be considered significant as 15 to 17 pairs of observations were recorded.

The standard errors $\frac{1-r^2}{(n-1)^{\frac{1}{2}}}$ calculated assuming a normal distribution have not been included in the above table since for small samples, when n is of the order of 17 as in the above case, the distribution is not normal. Consequently it is deceptive in the case of samples of this size to use the standard error calculated assuming a normal distribution. The significance of each correlation coefficient was determined from the appropriate table for small samples (R.A. Fisher, "Statistical Methods for Research Workers"

11th Edition, p. 209). All the coefficients in the above table are significant at the level represented by P = 0.01.

A comparison of these correlation coefficients shows that from the number of observations that it was possible to make in the experimental time available, there was no evidence to suggest that the Crampton Index was more highly correlated with the corrected effective temperature than it was with the wet bulb temperature. Since the rate of air movement in any one experiment was fairly constant and the differences in humidity were not excessive between experiments such a result might be expected. It has been shown, however, by the New York State Commission on Ventilation, as previously mentioned (p. 119) that variations in air movement cause significant differences in the value of the Crampton Index. Therefore, since air movement is one of the components from which the effective temperature is computed a full-scale comprehensive study of the effect of changes in environmental physical factors on changes in the Crampton Index over a wide range of temperature, humidity and air movement would probably indicate that the Index was more highly correlated with the effective temperature than with the wet bulb temperature. However, in the time available for the present study this was not possible.

The Crampton Index appears to be very sensitive to changes in temperature and therefore since a range of corrective effective or wet bulb temperature exists within which a single subject may feel comfortable as indicated by his or her subjective thermal sensations, according to the scale used (p. 63) there must also be a characteristic range of Crampton Index values observed within each individual subject's comfort zone in the transitory state. Furthermore, there will be a range of decreases observed for the Index from the comfort zone values due to an increase in temperature evoking a feeling of thermal discomfort and fatigue when experiments are carried out on a group of subjects.

Tables 5.2 and 5.3 show the values of the corrected mean value of the Crampton Index and b in the equation Y = a + bX, the relationship between the dependant variable, the Crampton Index (Y) and the independent variable, the wet bulb temperature and the corrected effective temperature (X) respectively for each of the six subjects' four tests in the experimental room.

TABLE 5.2

Constant b of the regression equation Y = a+ bX where
Y = Crampton Index
X = Wet Bulb Temperature °F.
Also the mean value of Y corrected for variations of the mean wet bulb temperature.

Subject No.	Corrected Mean Value of Crampton Index.				Value of b			
	RESTING		STEP-CLIMBING		RESTING		STEP-CLIMBING	
	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%
1	67.93	62.32	61.68	51.64	-1.51	-1.66	-2.56	-2.63
2	25.21	44.33	9.49	41.43	-1.99	-2.14	-3.37	-2.66
3	46.99	47.03	24.26	37.84	-1.60	-2.55	-2.06	-2.48
4	38.49	42.36	25.56	53.21	-2.59	-1.79	-3.24	-3.16
5	72.31	67.80	47.24	49.31	-1.33	-2.40	-1.98	-2.76
6	36.09	78.07	50.38	43.94	-2.79	-2.46	-2.39	-2.69

TABLE 5.3

Constant b of the regression equation Y = a + bX where
Y = Crampton Index.
X = Corrected Effective Temperature
Also the mean value of Y corrected for variations of the mean Corrected Effective Temperature.

Subject No.	Corrected mean value of Crampton Index.				Value of b			
	RESTING		STEP-CLIMBING		RESTING		STEP-CLIMBING	
	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%
1	74.30	66.10	75.51	50.52	-1.78	-1.71	-2.72	-2.29
2	26.98	37.46	13.63	44.11	-1.63	-1.69	-2.71	-2.71
3	44.22	36.23	26.42	23.90	-1.42	-2.32	-1.85	-2.71
4	36.03	34.89	46.33	43.90	-2.09	-1.53	-2.70	-2.45
5	75.40	64.62	66.52	34.54	-1.16	-1.98	-1.76	-2.09
6	53.08	70.57	48.23	35.89	-2.19	-1.91	-1.91	-2.23

It will be noted that all the values of b have a negative sign in Tables 5.2 and 5.3 which means that in every case increase in environmental heat was associated with a fall in the Crampton Index. The degree of fall was generally increased by exercise.

A comparison of these two tables with respect to the value of the regression constant b does indicate that they are slightly more consistent in Table 5.3 (Crampton Index and Corrected Effective Temperature).

An analysis of variance using the method described in Appendix 2.A. has been carried out to assess the significance of the effect of the two humidity levels and of step-climbing at a standard rate on the value of b, and also the effect of these same factors on the mean value of the Crampton Index during a single test after correcting for any variation of the mean value of the temperature.

The analysis has shown that the rate of decrease of the Crampton Index with both wet bulb and corrected effective temperature is not

THE CRAMPTON INDEX AND CORRECTED EFFECTIVE TEMPERATURE. REGRESSION LINES FOR ALL SUBJECTS.

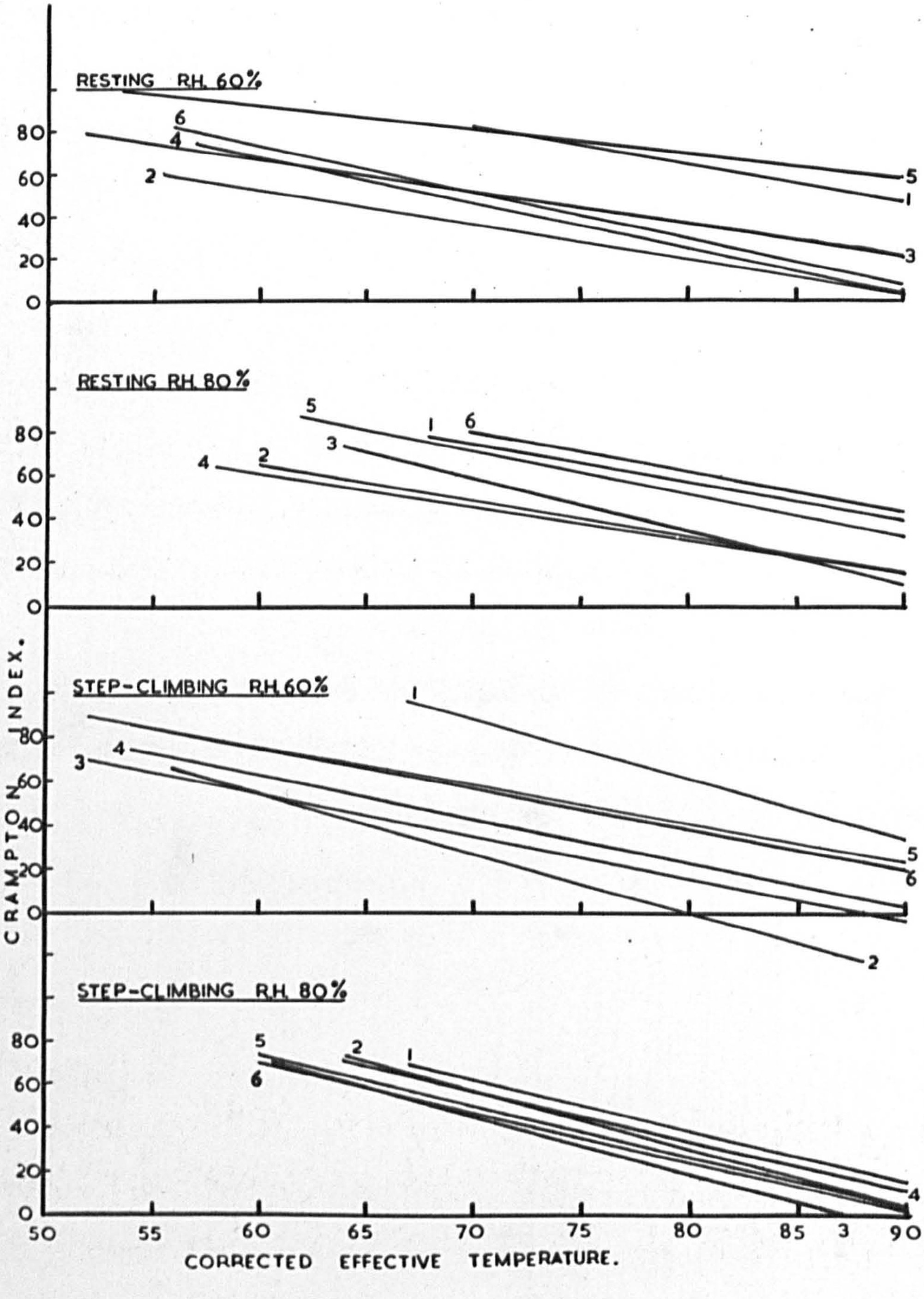


FIG. 5.1

significantly different in the envirements in which the relative humidity was 60% and 80%, but that in both cases for the two physical factors studied the rate of fall was significantly increased as a result of step-climbing at the fixed rate prescribed. Also the analysis indicated that generally speaking the rates of decrease were the same for all the subjects.

With regard to the mean value of the Crampton Index, corrected for variations of the mean temperature level between experiments, there was a significant difference between subjects both in respect of the wet bulb temperature and corrected effective temperatures. Furthermore, the mean value of the Index was significantly lower as a result of step-climbing, but the two humidity levels produced no significant differences.

Therefore the results indicated that the rate of fall of the Crampton Index was increased by the performance of muscular work when comparisons were made of observations on the six subjects in environments in which the temperature increases were comparable. In this respect the differences between the subjects were not significant.

However, each subject had a characteristic initial value which did not appear to affect the rate of fall of the Index when correlated with environmental temperature increases. Therefore, the regression lines would theoretically be a set of parallel lines at different levels for each subject. The regression lines for each of the four tests are shown in figure 5.1. For simplicity, the points from which the lines were calculated are not included on the graphs.

It will be seen from these figures that the above statements are substantially correct but some variations will be observed as is to be expected with physiological data. Such variations could be due to a number of uncontrollable factors, such as time and nature of last meal, pre-experimental activity and natural daily variations.

The following tables (5.4 and 5.5) show the mean values of the regression constant b and the corrected mean value of the Crampton Index for all the subjects. The data has been obtained from Tables 5.2 and 5.3. The standard deviations for assessing the significance of the differences between these means calculated from the Error variance of the analysis based on 15 degrees of freedom are also shown in the table.

TABLE 5.4

Mean Values for all Subjects of the Regression constant b, showing appropriate standard deviations (S.D.)

	Crampton Index Correlated with W.B. °F.				Crampton Index Correlated with C.E.T.			
	RESTING		STEP-CLIMBING		RESTING		STEP-CLIMBING	
	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%
Mean value of b for all subjects	-1.97	-2.17	-2.60	-2.73	-1.61	-1.86	-2.29	-2.41
Standard deviation	0.260		0.260		0.218		0.218	
Pooled resting and step-climbing values	-2.07		-2.66		-1.73		-2.35	
Standard deviation of pooled mean	0.184				0.164			

TABLE 5.5

Mean Values for all Subjects of the Mean Value of the Crampton Index for each test adjusted for the variations of the mean level of the temperature between experiments.

	Crampton Index and W.B. °F.				Crampton Index and C.E.T.			
	RESTING		STEP-CLIMBING		RESTING		STEP-CLIMBING	
	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%
Mean value for all subjects	48.84	56.98	36.43	46.23	51.66	51.64	46.10	38.80
Standard deviation (S.D.)	6.44		6.44		6.97		6.97	
Pooled resting and step-climbing values	52.41		41.33		51.65		42.45	
Standard deviation of pooled mean	4.55				4.93			

The value of t for 15 degrees of freedom = 2.131 (P = 0.05) from which it follows that a difference of at least S.D. x 2.131 is required for significance, e.g. difference between pooled resting and exercising values of the rate of change of Crampton Index with Corrected Effective Temperature = 0.62. A difference greater than 0.164 x 2.131 = 0.349 is required for significance. Therefore a difference of 0.62 is significant.

While it would appear from the present studies that little significanse can be attached to absolute values of the Crampton Index,

SUBJECT NO.4. CRAMPTON INDEX, FOREHEAD SKIN CONDUCTIVITY & SUBJECTIVE THERMAL SENSATIONS RELATED TO THE ENVIRONMENTAL TEMPERATURE.

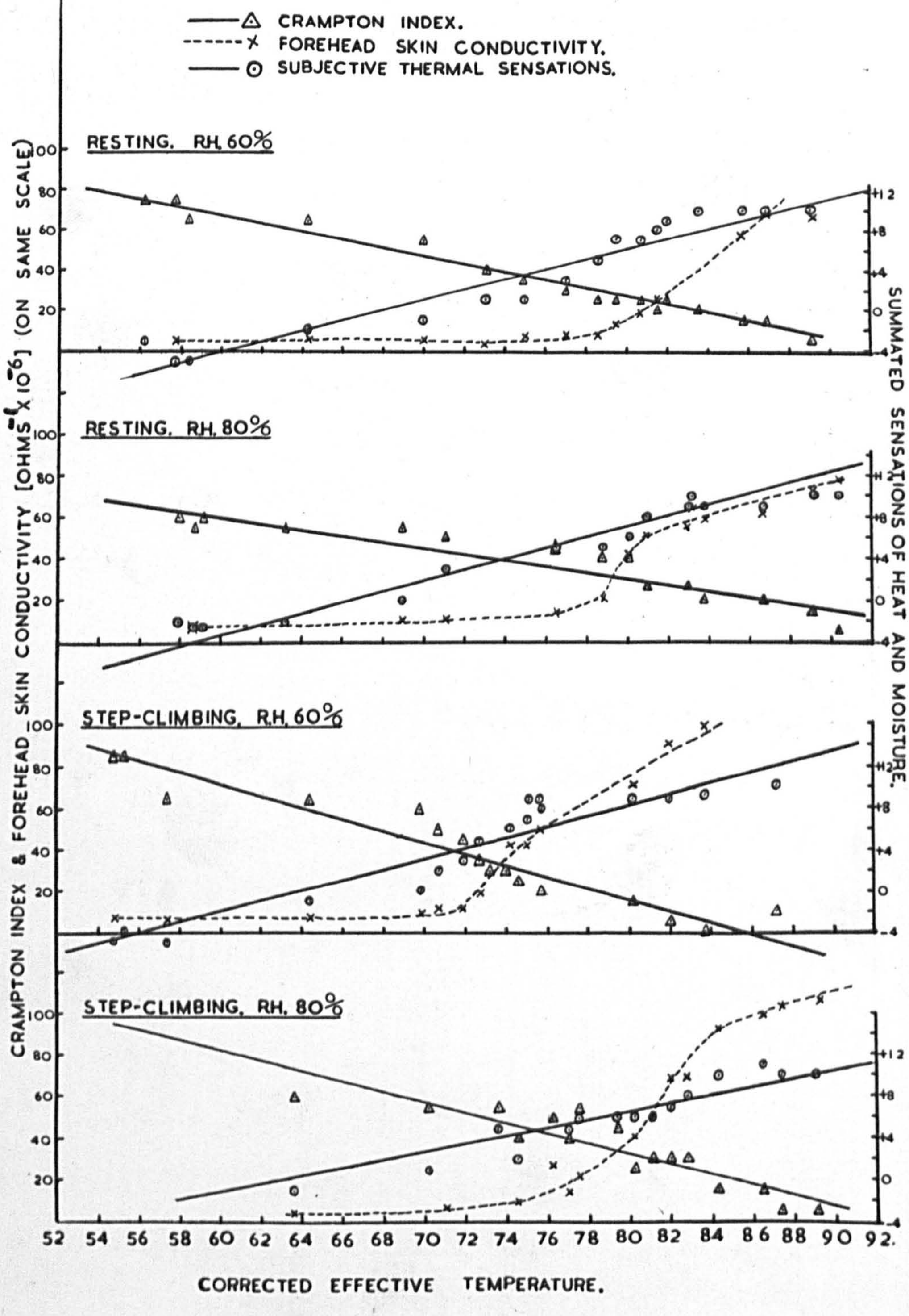


FIG. 5.2

significant changes occur in the index value as a result of thermal stress or muscular work (or both). The previous use of this Index, as discussed in Chapter II has been restricted mainly to the interpretation of the significance of absolute values. It has been found in many cases, however, taking as a basis the normal range, held by Crampton to be between 70 and 80 that such interpretations have not yielded results consistent with other criteria of physical fitness.

The original protocols for these experiments are included in the appendix, but from the data, figure 5.2 has been drawn to show the changes in the Crampton Index in relation to corrected effective temperature in the case of one of the six subjects who participated in these experiments. Similar graphs could be constructed for each of the subjects.

II Subjective Thermal Sensations

As previously indicated (p.74) Crowden and Lee (1946)(26) have found that equilibrium values of the summated sensations of heat and moisture were highly linearly correlated with both wet bulb temperature and the total heat of the air, which included the sensible and latent heats.

Table 5.6 shows the values of the correlation coefficients of the transitory sensations of warmth (the summated sensations of heat and moisture) with the corrected effective temperature, using the values which were recorded simultaneously with the observations of the Crampton Index. As was to be expected the correlations were highly significant since the temperature scale was based on the subjective thermal sensations of lightly clothed subjects.

TABLE 5.6

Correlation coefficients of transitory values of sensations of warmth (the summated sensations of heat and moisture) with the corrected effective temperature.

SUBJECT NO.	RESTING R.H. 60%	RESTING R.H. 80%	EXERCISING R.H. 60%	EXERCISING R.H. 80%
1	+ .0597	+ 0.953	+ 0.902	+ 0.987
2	+ 0.971	+ 0.909	+ 0.957	+ 0.965
3	+ 0.969	+ 0.841	+ 0.910	+ 0.905
4	+ 0.963	+ 0.987	+ 0.947	+ 0.743
5	+ 0.856	+ 0.972	+ 0.979	+ 0.983
6	+ 0.933	+ 0.888	+ 0.875	+ 0.943

As for the Crampton Index the effect of the two different humidity levels and of the step-climbing on the relationship between the subjective thermal sensations have been studied; the analysis of variance has been used to assess the significance of the findings. A summary of the results are shown in Table 5.7.

TABLE 5.7

Mean level of the summated sensations of heat and moisture corrected for differences in the mean temperature and the value of the regression equation

Y = a + bX where

Y = Summated Sensations of Heat and Moisture.

X = Corrected Effective Temperature.

	CORRELATED MEAN Value of Y				Value of b			
	RESTING		STEP-CLIMBING		RESTING		STEP-CLIMBING	
Subject No:-	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%	R.H. 60%	R.H. 80%
1	2.78	-1.17	1.20	2.86	0.63	0.57	0.67	0.74
2	1.73	1.31	2.77	3.16	0.35	0.35	0.38	0.49
3	3.47	5.60	3.90	3.35	0.28	0.51	0.37	0.41
4	4.18	4.50	5.91	4.84	0.52	0.45	0.54	0.36
5	2.32	2.20	5.57	4.90	0.27	0.47	0.49	0.43
6	2.10	1.13	3.19	4.49	0.21	0.55	0.35	0.40
MEAN VALUES	2.76	2.26	3.76	3.93	0.38	0.48	0.47	0.47
STANDARD DEVIATION	0.69		0.69		0.052		0.052	
POOLED RESTING AND STEP-CLIMBING VALUES	2.51		3.84		0.43		0.47	
STANDARD DEVIATION OF POOLED MEAN	0.49				0.037			

LEAST VALUE REQUIRED FOR SIGNIFICANCE = S.D. x 2.131 (P = 0.05).

It will be seen therefore that the amount of muscular work peformed during the experimental period does not produce a significant effect upon the rate of change of the transitory values of the summated sensations of heat and moisture with corrected effective temperature. However, the performance of step climbing at regular intervals of time appears to have the effect generally of increasing the subjective sensation of warmth by 1.33 points on the arbitrary scale for the same temperatures when the subject was (a) resting and (b) step climbing.

There was a significant difference between subjects with respect to the rate of increase of the subjective sensations of heat and moisture with corrected effective temperature as was to be expected. The rate of increase was greatest for Subject No. 1. There were no significant differences between subjects Nos. 2, 3, 5 and 6, whilst values of b for subject 4 were intermediate between those for subject 1 and the remaining subjects.

Therefore the rate of changes of the summated subjective sensations of heat and moisture does not appear to be affected by muscular work of the type and duration performed in these tests, but the mean level of the increases are higher and furthermore significant differences in this respect were revealed for the subjects. The interaction between subjects and treatments was not significant.

III. Forehead Skin Conductivity

Changes in the value of the skin conductivity were observed to assess the time of onset of sweating. Prior to the appearance of visible sweat on the forehead there was a gradual increase in the value of the skin conductivity which was probably due to increased peripheral blood flow and also to the presence of sweat in the glands immediately below the skin surface. It has been shown (Gagge, Winslow, Herrington, 1937)[43] that the degree of wetness of the skin due to sweating is affected by the ambient temperature and humidity and also by air movement. Therefore, changes in the skin conductivity have been considered in relation to the corrected effective temperature.

Initial values of the skin conductivity when the corrected effective temperature was between 51° and 68° were within the range 0.9 to 8.0×10^{-6} $ohms^{-1}$. The initial temperatures were, to a large extent, determined by the temperature of the air in the room in which the air conditioned cubicle was located.

The following table gives the initial observed values for the skin conductivity and the value associated with the first appearance of visible sweat on the forehead, together with the corrected effective temperatures.

TABLE 5.8

Values of skin conductivity and corrected effective temperature at time of appearance of visible sweat, where

a refers to subject resting, environmental R.H. 60%

b refers to subject resting, enviornmental R.H. 80%

c refers to subject step-climbing, environmental R.H. 60%

d refers to subject step-climbing, environmental R.G. 80%.

Skin conductivity shewn in units of $ohms^{-1} \times 10^{-6}$

SUBJECT NO.		INITIAL VALUE OF SKIN CONDUCTIVITY.	FIRST APPEARANCE OF VISIBLE SWEAT. Value of Skin conductivity.	Corrected Effective Temperature.
1	a	No	data available	
	b	1.40	No visible sweat	87.3
	c	2.22	28.3	85.0
	d	5.03	26.7	78.9
2	a	3.08	No visible sweat	86.0
	b	2.17	23.9	88.2
	c	2.00	27.3	84.1
	d	1.40	25.4	82.8
3	a	1.76	No visible sweat	85.4
	b	7.60	21.2	85.9
	c	1.46	21.2	77.0
	d	1.87	22.9	82.7
4	a	5.40	19.9	81.2
	b	7.20	22.6	79.4
	c	6.69	29.8	74.2
	d	6.0	26.2	77.5
5	a	1.64	No visible sweat	88.0
	b	5.40	22.7	88.5
	c	2.40	25.9	75.6
	d	2.89	23.6	83.4
6	a	1.00	No visible sweat	85.5
	b	7.60	34.6	84.1
	c	0.93	16.0	81.2
	d	2.40	27.2	84.4

From this table it will be seen that the performance of the muscular work provoked sweating to occur at a lower temperature than when the subject was in the resting state. In five of the observed cases for subjects in a state of rest, no moisture was present on the forehead skin surface at the end of the experiment and therefore a true mean value of the corrected effective temperature at the time of onset of sweating could not be obtained. However, when the subjects were exercising, sweating commenced before the end of the experimental period in every case. The mean value of the observed corrected effective temperature which accompanied the increases in skin conductivity and the appearance of visible sweat on the forehead was 80.5° with a standard deviation of 3.6°. That is, below that temperature the skin was generally dry, but slight increases in skin conductivity occurred before visible sweat appeared on the forehead. Thereafter, the increase in skin conductivity with temperature was very much more rapid. Upon reaching a value of the order of 60×10^{-6} $ohms^{-1}$ the rate of increase of skin conductivity with temperature generally appeared to decrease indicating the equilibrium phase between sweat excretion and evaporation. Further increases of skin conductivity are taken as being due to the presence of more sweat on the forehead skin surface due to the increased requirement of evaporation for body temperature regulation as the corrected effective temperature was increased.

Fig. 5.2 indicates the changes in skin conductivity, subjective thermal sensations of heat and moisture and Crampton Index with corrected effective temperature for Subject No.4.

IV CRAMPTON INDEX AND SUBJECTIVE THERMAL SENSATIONS.

The Crampton index has been shown to be sensitive to changes in the environmental temperature. The mean value calculated (Table 5.4) showed that the Index fell by 17.5 points per 10° increase in corrected effective temperature in the resting state and by 23.5 points per 10° increase when muscular work in the form of step climbing at regular intervals was performed. Therefore it follows that the greater the range of corrected effective temperature within which a particular subject may feel comfortable according to thermal and fatigue sensations then the comfort zone Crampton Index range will correspondingly become wider. Also there are differences in this respect for each subject with the result that no significance could be attached to absolute values of the Crampton Index. However, some indication is necessary of the changes in the Crampton Index from the comfort zone values which can be associated with the commencement of thermal discomfort.

Therefore using as a basis the recordings of the subjective thermal sensations of heat moisture and freshness for the assessment of the comfort zone in terms of corrected effective temperature the relevant ranges of Crampton Index values have been computed. Also the range of decreases in the value of this Index consistent with each subject expressing, when asked, a thermal sensation of +3 (too warm) on the heat sensation scale or +3 (too humid) on the moisture sensation scale have been computed.

The results obtained from this analysis are shown in the following tables:

TABLE 5.9

Comfort Zone Range of Crampton Index (C.I.) values and corrected effective Temperature (C.E.T.)

Within the ranges shown all subjects felt comfortably warm (+1) or comfortably cool (-1).

Subject No.	RESTING R.H. 60%	RESTING R.H. 80%	STEP-CLIMBING R.H. 60%	STEP-CLIMBING R.H. 80%	RANGE OF:
1	80-65 69.0-76.9	70-75 77.0-81.2	75-65 72.0-74.0	75-65 71.2-73.8	C.I. C.E.T.
2	50-45 68.2-71.0	50-20 71.2-83.2	60-15 56.5-74.2	75-40 65.0-76.1	C.I. C.E.T.
3	70-60 56.5-69.8	55 68.2-73.0	55-20 56.4-75.3	55-25 59.5-79.0	C.I. C.E.T.
4	65-35 64.3-75.0	60-55 57.9-69.0	65-60 64.4-69.8	60-55 63.6-70.2	C.I. C.E.T.
5	90-85 64.8-75.7	85-60 67.8-77.5	65 166.0-69.0	70-60 57.5-69.5	C.I. C.E.T.
6	75-60 55.7-73.8	80-65 66.2-80.2	85-55 55.4-76.2	65-50 60.1-67.5	C.I. C.E.T.

Where only 1 value is given, as for example Subject No. 5, step-climbing R.H. 60%) a subjective thermal sensation within the range plus 1 to minus 1 on the heat or moisture scale was only expressed once at the time the Crampton Index was assessed during the experimental period.

TABLE 5.10

Observed value of Crampton Index (C.I.) and Corrected Effective Temperature (C.E.T.) when subjective thermal sensation of + 3 (too warm) on the heat sensation scale or +3 (too humid) on the moisture sensations scale was first expressed.

Subject No.	RESTING				STEP-CLIMBING.			
	R.H. 60%		R.H. 80%		R.H. 60%		R.H. 80%	
	C.I.	C.E.T.	C.I.	C.E.T.	C.I.	C.E.T.	C.I.	C.E.T.
1	70	81.2	45	85.9	65	77.1	35	78.2
2	10	80.8	5	86.3	-10	81.0	30	81.3
3	35	82.2	35	81.1	10	81.3	25	82.8
4	25	78.6	45	76.5	50	70.7	40	77.0
5	65	82.6	50	83.2	55	73.8	55	74.8
6	25	82.4	55	84.1	30	80.4	25	84.2

Tables 5.9 and 5.10 give the ranges of temperature and Crampton Index values previously referred to. In table 5.10, although obvious individual differences are apparent for the Crampton Index values it is clear that thermal discomfort was felt at lower corrected effective temperatures when the subjects were step-climbing than when resting. The corresponding mean values of the corrected effective temperatures were 82.07° (resting) and 78.54° (step climbing), each being the mean of 12 observations. Thus there was a difference of 3.53° for the temperature at which thermal discomfort was first evoked. The standard error of this difference was 1.126 ($t = \frac{3.53}{1.126} = 3.135$; $P = 0.05$).

Table 5.9 shows that the wider the range of temperature for the comfort zone the greater was the variation in Crampton Index values. Thus in the case of Subject No. 6. a C.E.T. range of 20.8° was associated with a C.I. range of 30, whilst a C.E.T. range of 7.4° was found to have been the case when the C.I. range was 15.

Table 5.11 shows the decreases from the mean value of the Crampton Index comfort zone range that were observed simultaneously with the commencement of thermal discomfort based on the preceding hypothesis. The resting and exercising values have been pooled in this table.

TABLE 5.11

Crampton Index decreases from mean comfort zone value associated with the onset of thermal discomfort.

SUBJECT NO.	MEAN C.I. WITHIN COMFORT ZONE	DECREASE OF C.I. ASSOCIATED WITH 3 heat sensation or moisture sensation scales. (mean of 4 values).
1	65	-16.7
2	37.5	-20.0
3	47.5	-23.75
4	50.0	-10.0
5	75.0	-31.25
6	67.5	-40.00

Expressed in terms of measurable units of the Crampton Index this yields the mean figure of 25 with a standard deviation of approximately 10 units. However, as a basis for attaching significance to such changes in the value of the Crampton Index the initial calibration of the subject over his or her complete comfort zone temperature range is required. As this cannot obviously be achieved in field studies where experimental procedures are not controlled some other definition for the range of minimal changes in the Crampton Index to be associated with circulatory changes accompanying the onset of subjective thermal stress must be formulated.

Thus the Crampton Index at the lower or cool limit of the comfort zone is taken as the basal value from which the changes associated with the onset of thermal discomfort have been assessed. Working on this basis the mean decrease of the Crampton Index (24 observations) was found to be 32.08 units with a standard deviation of 15.54.

Therefore, taking the range in decreases for the Crampton Index to be between 15 and 45, with a mean value of 30, 75% of the observed decreases were seen to fall within this range. Hence it would seem reasonable to assume that circulatory changes evoked by increased enviornmental temperature or the performance of muscular work, or a combination of both factors, which were associated with the onset of subjective thermal discomfort are such as to cause a decrease in the Crampton Index of between 15 and 45 units with a mean value from 24 observations of approximately 30. Also the probability would be at least 0.7 that unit decrease in the Crampton Index from a comfort zone value within this range or above its upper limit of 45, might be associated with the onset of thermal stress and discomfort.

A similar calculation showed that the corresponding decrease in the Crampton Index to the time of onset of sweating was 40 units with a standard deviation of 15 (to the nearest measurable units). The corresponding mean value of the subjective thermal sensation of moisture was 3.2 on the arbitrary scale.

The correlation between summated subjective thermal sensations of heat and moisture and Crampton Index for each subject has shown that generally the rate of increase in thermal sensations with decreases in Crampton Index is constant for all subjects but that the general regression level showed differences between subjects as was previously indicated. The results are summarised in Tables 5.12 and 5.13.

TABLE 5.12

Correlation of the transitory values of the Summated Thermal Sensations of Heat and Moisture with the Crampton Index.

SUBJECT No.	NO. OF OBSERVATIONS	CORRELATION COEFFICIENT
1	54	-0.768- 0.056
2	63	-0.749- 0.035
3	65	-0.821- 0.041
4	67	-0.922- 0.018
5	67	-0.897- 0.024
6	66	-0.746- 0.055

TABLE 5.13

Mean value of the Crampton Index corrected for Differences in the mean value of the subjective sensations of heat and moisture and also the value of b of the regression equation.

$Y = a + bX$

where Y = Crampton Index

X = Summated Sensations of heat and moisture.

SUBJECT NO.	CORRECTED CRAMPTON INDEX MEAN VALUE.	VALUE OF b
1	59.3	-2.75
2	27.1	-4.55
3	37.6	-4.06
4	54.3	-4.02
5	55.9	-4.39
6	45.2	-4.35

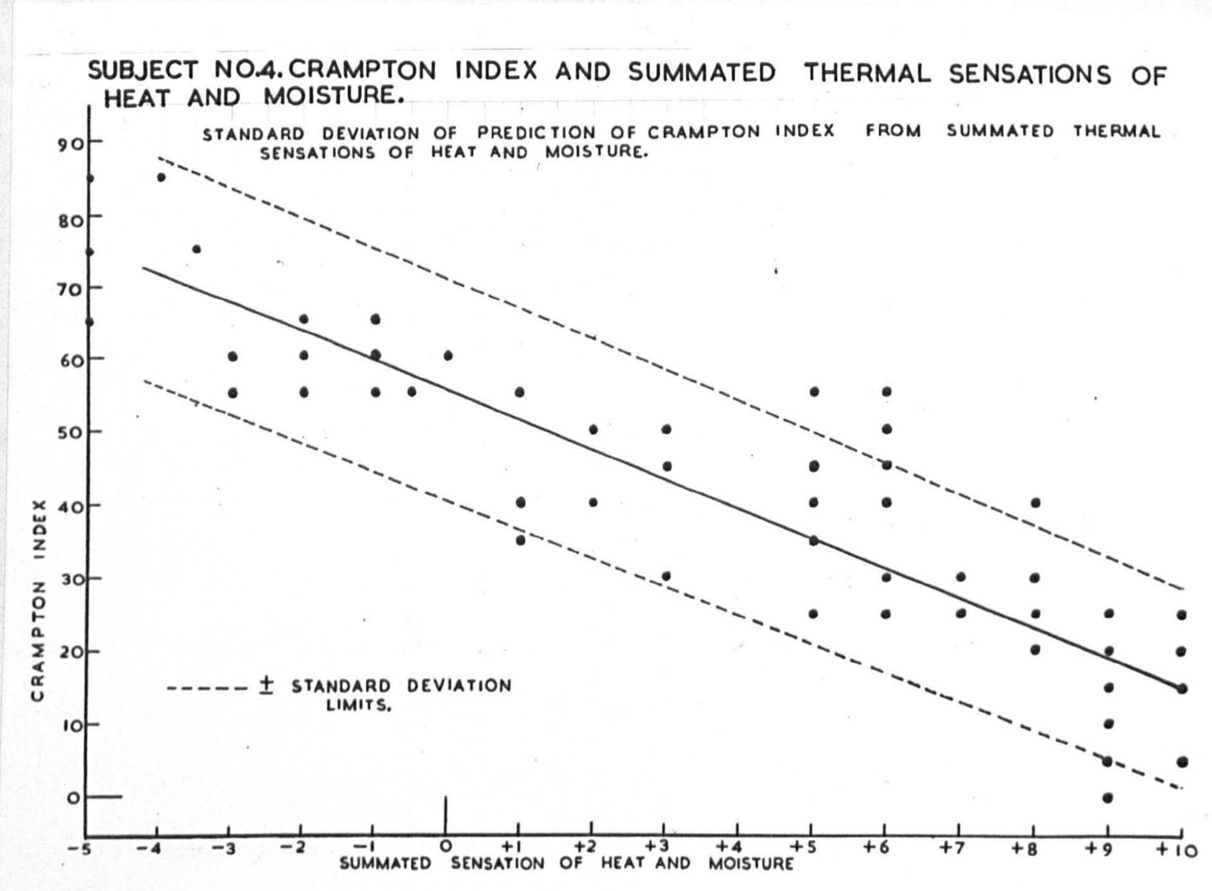

SUBJECT NO.4. CRAMPTON INDEX AND SUMMATED THERMAL SENSATIONS OF HEAT AND MOISTURE.
STANDARD DEVIATION OF PREDICTION OF CRAMPTON INDEX FROM SUMMATED THERMAL SENSATIONS OF HEAT AND MOISTURE.
CRAMPTON INDEX
SUMMATED SENSATION OF HEAT AND MOISTURE
----- ± STANDARD DEVIATION LIMITS.
90
80
70
60
50
40
30
20
10
0
-5
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10

FIG. 5.3

From table 5.13 it will be seen that except for Subject No. 1 the regression constant b was not significantly different from one subject to the other, and the values of b calculated separately from each test did not appear to depend upon the activity of the subject or upon the mean humidity level.

Figure 5.3 shows the correlation between the Crampton Index and Summated thermal sensations of heat and moisture for Subject No. 4 and also the standard deviation of prediction of Crampton Index values from Summated thermal sensations.

Conclusions

These results have shown that the circulatory changes that occur on exposure to gradually increasing air temperatures are such as to cause changes in the Crampton Index which become more marked as a result of the performance of a standard amount of exercise at regular intervals of time. This Index, when used in the User-test experiments described in Chapters III and IV had also shown consistent changes which appeared to be related to the enviornmental temperature and air movement and also to the amount of muscular work carried out by the subjects. Therefore, these changes in the value of the Crampton Index did show that as a result of increased ambient temperatures combined with the performance of muscular work, the subjective thermal sensations increased. As the subjects began to feel fatigued the vaso motor mechanism failed to react adequately and an increase in the heart rate occurred in an effort to counteract diminished tension in the blood vessel walls. Hence these controlled experiments confirmed the deductions drawn from the User-test experiments with regard to the physiological significance of changes in the value of the Crampton Index.

The relationship between the algebraic sum of the numerical equivalents of the various gradations in the subjective thermal sensation scales of heat and moisture (the sensation of warmth) and the corrected effective temperature was also shown to be modified for the subjects when exercising. The scale had originally been devised for assessing the thermal comfort vote of subjects at rest or whilst performing light sedentary tasks. However, in the present experiments the scale has been used for subjects performing muscular work. The results showed that whilst the rate of increase of the subjective thermal sensations of heat and moisture with corrected effective temperature was not altered, the values appeared to be higher by approximately 1.3 graduations when compared with the resting values for equal temperatures and humidities over the range considered.

Since both the decreases in the Crampton Index and the increases in the summated sensation of heat and moisture were both more marked as a result of exercise this physiological index was correlated with the subjective thermal sensations for each subject. The correlation coefficients together with the corresponding standard errors are shown in Table 5.12.. However, the most interesting result was that the rate of decrease of the Crampton Index with increases in the subjective thermal sensations appeared to be not significantly different for five (Nos. 2-6) out of the total of six subjects. As already mentioned the clothing worn by Subject No. 1 was heavier than that worn by the others. Since an analysis of the comfort zone values of the Crampton Index had shown that each subject appeared to have a characteristic range of values which was not the same for all subjects a single regression line for the relationship between these two variables was consequently not adequate. However, since the slopes of these lines were generally equal it does appear that changes in the Crampton Index and not absolute values may form a basis for assessing increased thermal stress, discomfort and fatigue sensations.

Having this in mind, the decreases in the value of the Crampton Index for an increase in heat or moisture sensations to +3 on the arbitrary scale were examined. The results showed that from the mean comfort zone values the Crampton Index decreased by 25 units with a standard deviation of 10 units, when considering all the subjects together. When assessed from the lower (or cooler) limit of the comfort zone the corresponding decrease value was 30 with a standard deviation of 15. Thus a subjective sensation change from comforably cool or moist to too warm or too moist was found to be associated with a Crampton Index change of 30 ± 15.

Further examination of the data showed that the onset of sweating occurred when the skin conductivity reached the value of approximately $20 \text{ ohms}^{-1} \times 10^{-6}$ and the corresponding mean value of the thermal sensation of moisture was +3 on the scale. Before the appearance of visible sweat on the forehead there was a gradual increase in the value of the skin conductivity from the initial value due presumably to increased peripheral blood flow and the presence of sweat in the glands immediately beneath the skin surface. The corresponding fall, from the lower (or cooler) limit of the comfort zone of the Crampton Index which occurred at the time of onset of sweating was found to be

40 units with a standard deviation of 15.

From these considerations it seems justifiable to deduce that changes in Crampton Index may be highly correlated with environmental thermal changes and affected by the performance of muscular work. The data has also been used to ascertain the limits of the range of decreases in the Crampton Index which occur at the time of onset of thermal stress and also at the time when profuse sweating was first evoked for body temperature control.

Summary.

1. Following the User-test studies a series of controlled experiments has been carried out in an air conditioned room with the temperature and humidity controlled at various levels to test the validity of the correlation between the physiological reactions and subjective thermal sensations employed in the User-test experiments and the changes in room climate. The effect of performing a standard amount of exercise at regular intervals has also been investigated.

2. Six medical students, 2 women and 4 men, in the age groups 20 to 30 years, acted as subjects and each participated in four experiments, twice at rest throughout the experimental period and twice when they performed the prescribed step-climbing. Two humidity levels, approximately 60% and 80% were maintained in the experimental room for each subject's resting and exercising test whilst the wet and dry bulb temperatures were gradually increased over a four-hour period.

3. The physiological changes studied on the six subjects were (a) changes in the vaso motor tone as indicated by the Crampton Index,

(b) the time of onset of sweating as indicated by changes in skin conductivity, (c) subjective thermal sensations of heat, moisture and freshness.

4. One observer recorded the data from which the values of the Crampton Index were computed whilst a second observer questioned the subjects regarding their thermal sensations and took readings of the wet and dry bulb temperatures as given by a whirling hygrometer, silvered and globe thermometer temperatures and kata thermometer cooling times from which values of the air velocity were computed at regular intervals throughout the experimental period.

5. The results obtained indicated that:-

(a) The Crampton Index was very sensitive to environmental temperature changes and to the performance of muscular work.

(b) The relationship between the summated thermal sensations of heat and moisture and corrected effective temperature was modified as a result of the subjects performing exercise at regular intervals.

(c) Marked increases up to 20×10^{-6} $ohms^{-1}$ of the skin conductivity occurred at the time of onset of sweating.

(d) A relationship between subjective thermal sensations of heat and moisture and the Crampton Index was established and a range of decreases of the Crampton Index for the six subjects from the comfort zone values to the time of onset of thermal discomfort and sweating was determined.

DISCUSSION

This study has been concerned with the changes in room climate that occur as a result of domestic washing operations and their physiological effects upon the occupants with a view to establishing a scientific basis for formulating recommendations for the full use of provisions available for ventilation and washing which are installed in houses of modern design.

This domestic operation was chosen for study because it is well known that marked changes in room climate can occur in kitchens as a result of the housewife performing a weekly family wash particularly when use is made of a gas wash boiler, an appliance in common use and supplied to dwellings on post-war housing estates.

The extensive surveys which have been carried out in industry to demonstrate the relationship between the thermal characteristics of the environment, physiological reactions and subjective sensations do not appear to have been fully extended into the home environment.

Therefore, having developed a technique for the rapid assessment of changes in room temperature and humidity which would not impede housewives in the execution of their tasks it was applied to a detailed investigation of the magnitude of the changes in room climate that occur as a result of a gas wash boiler being lit for a time which conformed approximately with user practice. The purpose of this investigation was to ascertain the effects of different ventilating rates and methods and to formulate a recommended air change rate which would be effective in maintaining a comfortable working atmosphere throughout an experimental period of four-and-a-quarter-hours.

It was indicated that for a room of the size considered (1,000 cu.ft) an air change rate of at least 18,000 cu.ft. per hour was necessary for the maintenance of a comfortable working atmosphere. Such an air change rate could be effected by a 9" x 9" extractor fan with an air delivery of 300 cu.ft. per minute or by the full opening of windows and doors. However, this air change rate did not necessarily suffice for the control of moisture. There was a marked reduction in the absolute humidity of the air, but considerable condensation on walls, furnishings and the floor was observed even in the remote corner of the room.

However, a result of particular interest was afforded by the use of a coal fire and a hopper window as a means of ventilating the room. This method appeared to reduce considerably the condensation by maintaining the wall and floor surface above the dew point temperature whilst at the same time reducing significantly the relative humidity increases and by virtue of the increased room ventilation rate to approximately 10 room air changes per hour caused a significant reduction of the increases of temperature in the working space. These reductions, although not so marked as those afforded by the use of the extractor fan or the opening of windows and doors did indicate that such a means of ventilating a kitchen or kitchen living room may prevent the development of excessively high air temperatures and humidities in winter time when the full use of windows and doors may not always be practicable owing to external weather conditions. Therefore, it may be stated that unless a special method, such as ducting for the extracion of the products of combustion and heat from the immediate vicinity of the gas wash boiler is installed a minimum air change rate of 18 room air changes for the maintenance of comfortable working atmosphere is necessary. The control of moisture appeared to be a more difficult problem and for this a solid fuel flue as recommended in Post War Building Studies No. 19 for the control of kitchen odours, should be made use of, particularly in winter time.

Having established this, the study was extended to an investigation into the physiological and subjective thermal reactions in the first instance of a normal housewife and a trained domestic scientist who acted as subjects in a series of experiments which were carried out at the Field Test Unit, Boreham Wood, Herts. The purposes of these preliminary experiments were to determine the nature and extent of the changes in certain physiological reactions which might occur as a result of performing a weekly wash for the average family of four persons, and also to determine appropriate techniques for the assessment of their physiological reactions and subjective thermal sensations which would cause the least disturbance to the subjects during the performance of the specified domestic task.

For this purpose, observations on the resting and standing values of the systolic and diastolic blood pressures and pulse rates, together with measurements of the values of the skin conductivity, increases in which appeared to indicate the time of onset of sweating were employed.

It was found after a detailed analysis of the data that a single component of blood pressure or pulse rate did not appear to give results which could be considered consistent with the environmental thermal changes that occurred, the times of performance of maximum muscular effort, also the opinions of the subjects during and after each test, and from their subjective thermal sensations of heat, moisture and freshness which were considered as being reliable.

Therefore, a review was necessary of the physiological indices which could be of use in the present studies to assess thermal stress and fatigue and which were based on blood pressure and pulse rate components. It was found that the Crampton Index computed from the differences between lying and standing systolic blood pressures and pulse rates gave consistent results. The formulation of this index was based upon arguments first introduced by Leonard Hill in 1895 in support of reactions to a postural change as a test of physical condition. These arguments, with which Crampton appeared to be in complete agreement, were that in fit and healthy young people there would be a slight increase in systolic blood pressure, accompanied by a slight increase in pulse rate on rising from a supine to an erect position. This reaction occurred in order to compensate for the effect of gravity which would force all the blood into the lower half of the body if it were not for the contraction of the leg muscles upon the veins, increased abdominal pressure and the contraction of the muscles in the walls of the veins, particularly of the splanchnic vessels. However, it was further argued that in fatigued persons these mechanisms would not react to the same effect and consequently there would be a decrease in systolic blood pressure accompanied by a marked increase in heart rate to counteract increased gravitational attraction on the blood upon assuming an erect position.

Crampton's scale has received considerable criticism on the ground that absolute values of the Index calculated from it do not give valid indications consistent with other criteria of physical fitness. Thus absolute values between 70 and 80 were considered by Crampton as being within the normal range. However, the present study demonstrated that certain changes in the value of the Index for a subject are associated with the onset of thermal stress and fatigue sensations experienced in hot and humid environments.

Having established an experimental technique for the rapid assessment of changes in room climate and physiological reactions associated with these changes and the performance of muscular work, a second and more detailed series of user-test experiments were carried out.

With the improved techniques and the use of both working and control resting subjects the experiments were carried out to ascertain whether or not a problem of climate control could arise in a room of that type when full use was made of the windows and doors as a means of ventilating the room and also to study the extent of the changes in the physiological reactions and subjective thermal sensations when the changes in room climate were almost maximal corresponding to the case where the ventilation was restricted to the use of a single hopper window only.

The results clearly indicated that an air change rate of the order of 18 room air changes per hour was necessary for the maintenance of a comfortable working atmosphere, which confirmed the findings of the preliminary physical experiments. It also appeared that a ventilation rate of that order was not necessary throughout the complete experimental period but that it was necessary as soon as the water in the gas wash boiler had boiled and the transferance of the washed articles to the sink commenced.

When the ventilation rate was purposely restricted the marked increases in temperature and humidity that occurred combined with the performance of considerable muscular effort involving the scrubbing, rinsing and wringing of the articles gave rise to marked decreases in the Crampton Index from the initial resting values and marked increases in the subjective thermal sensations. The subjects also remarked that they felt very tired at the end of the experimental period. Also on these days the control subjects' physiological and subjective reactions were such as to indicate increased thermal discomfort even though they were at rest in the corner of the room furthest from the working space.

The interpretation of these findings had been based on the assumption of the significance mainly of changes in the Crampton Index and subjective thermal sensations. Therefore a further series of experiments were necessary to determine the validity of the correlation between these indices and the environmental warmth and also to assess the effect of muscular work.

These experiments were conducted in an air condition cubicle. They confirmed the theory that it was in the changes that occurred in the Crampton Index that made it of considerable value as a physiological index of reactions in the experiments of the type considered. The results demonstrated that the Crampton Index was very sensitive to changes in the environmental temperature and appeared to be linearly correlated with the corrected effective temperature over the range 55° to 90° considered. This index and the subjective thermal sensations of heat and moisture also appeared to be affected by the performance of muscular work in hot and humid atmospheres which led to the conclusion that the changes observed in the user-test experiments were undoubtedly due to muscular work and that the differences observed between the two days on which each housewife acted as a working subject were due to the increased environmental temperatures and humidities and reduced air movement resulting from inadequate ventilation of the working space.

The field survey which is part of this whole investigation to collect data of the changes in room climate and to study routine procedures which occur during washing operations is still in progress. However a preliminary examination of the information so far obtained shows that housewives have ralised through experience that it is necessary to control temperature and humidity in rooms when washing is carried out. Some housewives who wash and scrub on days when they also boil the soiled white articles appear to make considerable use of the ventilating appliances available in houses of modern design and other housewives who used to feel exhausted after a day of clothes washing now devote two days to the task. They arrange the routine so that they do not have to perform heavy muscular work at the same time as the gas wash boiler is in operation. In other words, the articles not intended for boiling are washed on one day and on a subsequent day they use the wash boiler for white articles. Any musbular work which may be necessary is carried out after the gas wash boiler has been turned off and the temperatures and humidities have fallen considerably below the peak values. It would appear from data of the Crampton Index decreases and observation on subjective thermal sensations that the latter technique is desirable on physiological grounds and should be followed on days when the gas wash boiler has to be used.

From the experience gained in these pilot user-test studies a number of experiments were carried out in which both working and control resting subjects participated. These experiments were conducted in order to compare the physiological reactions and subjective thermal sensations that occurred as a result of the performance of clothes washing when the means for obtaining the recommended air change rate were made available to the working subjects with these same physiological reactions that occurred as a result of performing exactly the same task when the ventilation rate was restricted to approximately 3 room air changes per hour. The results indicated that considerable thermal stress was imposed on the working subjects when the ventilation rate was reduced but that the opinions of the subjects together with the changes in the physiological reactions observed indicated that the air change rate recommended from the physical study was sufficient for the maintenance of a reasonably comfortable working atmosphere.

The validity of the changes in the physiological reactions and subjective thermal sensations as indications of thermal stress due to increased environmental temperature and a fixed amount of muscular work were then carried out under controlled conditions in an air conditioned cubicle. These experiments appeared to confirm the interpretation of the results from the user-test experiments.

Finally, some of the preliminary results of a field investigation which is still being carried out in houses of modern design and which is to be part of the whole study of this particular problem, have been indicated.

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APPENDIX I.

Protocols of Experiments on the Assessment of Changes in room climate due to the operation of a [illegible] gas wall boiler according to [illegible] practice.

Experiments conducted at the Field Test Unit of the Building Research Station, [illegible], Herts.

APPENDIX

APPENDIX I.

Protocols of Experiments on the Assessment of Changes in room climate due to the operation of a domestic gas wash boiler according to common practice.

Experiments conducted at the Field Test Unit of the Building Research Station, Boreham Wood, Herts.

Expt. Ref. FIRE OFF; HOPPER CLOSED (CONTROL)

DAY 1.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	52·5	56·8	54·1	57·0	50·7	66·7	52·3	57·5	62·5	57·0	51·1	56·6
15	52·3	56·5	53·9	56·5	50·7	55·5	52·5	67·5	53·0	57·3	51·1	55·5
30	52·5	56·8	53·9	56·8	50·9	55·7	54·5	59·9	54·5	69·2	51·8	56·1
45	58·4	62·0	58·0	61·8	54·7	58·6	59·2	63·9	58·2	62·3	53·7	57·3
60	62·3	65·9	61·6	65·2	55·7	60·2	62·5	67·4	61·1	64·9	55·7	58·4
75	64·7	68·1	63·9	67·4	57·5	61·6	64·7	68·7	63·2	66·3	56·3	58·8
90	73·2	74·1	70·0	72·5	58·6	62·5	74·3	75·1	69·4	71·5	58·8	59·9
105	77·7	77·8	73·9	75·5	59·7	63·9	78·5	79·5	73·7	75·1	59·2	60·8
120	70·0	71·9	69·2	70·0	59·5	62·9	69·2	70·0	68·3	68·3	59·0	61·1
135	66·3	68·7	66·5	67·6	59·0	62·5	65·9	67·4	65·4	66·3	58·4	61·1
150	64·5	67·0	64·9	66·5	58·6	61·6	64·1	66·3	64·1	65·7	58·0	60·6
165	63·5	66·1	64·1	65·7	58·6	61·6	63·2	65·4	63·2	64·7	58·2	60·2
180	62·7	65·2	63·2	64·7	58·4	61·3	62·3	64·9	62·5	64·3	58·2	60·2
195	62·0	64·7	62·7	64·3	58·0	60·8	61·6	64·3	62·0	63·7	57·5	59·9
225	61·1	63·7	61·6	63·2	57·5	60·4	60·4	63·5	60·8	62·9	57·0	59·5
255	59·5	62·5	60·2	61·8	57·0	69·5	58·8	62·5	59·7	62·0	56·8	59·0.

Expr. Ref. (1)

DAY2

Pos	I_1		I_2		I_3		II_1		II_2		II_3	
TIME.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	52.3	57.0	63.7	66.8	50.5	55.7	52.8	58.0	53.3	57.5	51.6	55.7
15	52.5	57.0	53.9	57.0	50.5	55.7	52.5	58.4	53.5	57.8	51.6	55.9
30	52.8	57.6	54.3	57.5	51.1	56.3	55.0	60.8	55.0	59.7	52.1	56.5
45	59.7	62.9	58.6	63.2	54.5	59.5	60.4	65.2	58.8	63.2	54.1	57.5
60	61.8	66.1	61.1	65.7	56.5	60.8	62.3	67.0	60.8	64.7	55.5	58.4
75	64.5	68.3	63.9	67.8	57.8	62.3	65.2	69.2	63.2	66.6	55.9	58.8
90	71.5	72.9	68.1	72.1	59.0	63.9	74.6	75.9	69.8	71.9	58.4	60.4
105	77.3	77.7	73.4	75.9	60.6	64.9	78.3	79.0.	73.7	75.1	59.5	61.3
120	69.2	71.7	69.4	70.3	60.6	64.1	68.7	70.0	67.4	68.7	59.0	61.3
135	66.5	69.2	67.2	68.1	60.2	63.5	66.3	68.3	65.9	67.2	58.8	61.1
150	64.9	67.4	65.7	66.5	59.5	62.7	64.5	67.0	64.3	66.1	58.0	60.8
165	63.5	66.1	64.3	65.7	58.8	62.3	62.9	65.7	63.2	65.2	58.0	60.6
180	62.7	65.4	63.2	64.9	58.8	61.8	62.0	65.2	62.7	64.7	57.5	60.2
195	62.0	64.7	62.7	64.5	58.4	61.3	61.8	64.7	62.3	64.3	57.0	60.2
225	60.8	63.9	61.8	63.7	57.8	60.6	60.6	63.9	61.1	63.5	57.0.	59.7
255	60.4	63.7	61.1	63.5	57.5	60.6.	59.9	63.9.	60.6	62.9.	56.3	59.7.

Expt. Ref. (1)

DAY 3

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	37.0	40.5	38.4	40.8	36.3	40.3	37.9	41.3	37.7	40.8	37.0	40.5
15	37.7	41.0	38.7	41.0	36.5	40.5	38.4	41.9	37.9	41.0	37.7	41.0
30	38.2	41.7	39.4	41.7	37.3	41.5	40.5	44.7	40.0	43.5	38.4	41.9
45	45.6	47.9	44.7	47.9	40.5	44.4	46.5	49.7	45.2	47.5	40.8	43.3
60	48.8	51.1	48.1	51.1	42.4	45.8	49.1	52.1	47.0	49.3	42.1	44.2
75	51.1	53.9	50.3	53.3	43.8	47.2	51.3	54.3	49.5	51.1	42.8	45.2
90	54.5	56.8	53.0	55.9	44.7	48.4	58.8	60.6	54.3	56.5	44.4	46.5
105	64.3	64.9	59.2	60.8	47.5	48.6	65.9	66.1	60.2	60.8	45.4	45.6
120	57.0	57.0	55.9	55.9	47.0	48.8	54.5	55.0	53.7	53.7	45.2	46.5
135	52.5	54.3	53.0	53.7	46.1	48.4	52.1	53.3	51.6	52.1	44.9	46.3
150	51.1	53.3	51.3	52.5	45.6	48.4	50.7	52.3	50.3	51.1	44.4	46.3
165	50.3	52.5	50.7	51.8	45.4	48.4	49.7	51.6	49.5	50.7	44.7	46.5
180	49.5	51.8	50.0.	51.3	45.6	47.9	49.3	51.1	49.1	50.3	44.2	46.5
195	49.1	51.3	49.7	50.9	45.2	47.9	48.8	50.9	48.8	49.7	44.4	46.6
225	48.8	51.1	49.1	50.5	45.4	47.9	47.9	50.5	47.9	49.5	44.2	46.3
255.	47.9.	50.5	48.7	49.7	44.7	47.7	47.5	50.0	47.7	49.3	43.8	46.1

Expt. Ref. (1)

DAY 4

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	43·8	46·1	45·2	46·1	43·1	45·8	44·2	47·0	44·2	46·5	43·3	45·8
15	44·2	46·3	45·2	46·5	43·3	45·8	44·2	47·2	44·2	46·5	43·3	46·1
30	44·4	47·0	45·4	47·2	43·8	46·3	46·7	49·3	45·8	48·8	43·8	46·7
45	50·9	52·8	49·3	52·5	46·3	49·3	52·3	54·3	50·5	53·3	46·1	48·1
60	54·1	56·5	52·8	56·1	47·9	51·1	54·7	56·8	53·0	55·3	47·5	48·8
75	56·3	58·6	55·0	58·0	48·6	51·6	57·5	59·2	55·3	57·3	48·8	50·3
90	64·7	65·4	60·4	60·6	50·7	53·0	66·5	66·8	61·8	63·7	50·3	51·1
105	70·6	70·6	65·7	67·2	52·8	54·5	71·3	71·3	66·1	67·4	51·1	51·6
120	63·2	63·2	62·0	61·8	52·5	54·3	61·3	61·3	60·2	59·9	52·1	52·5
135	58·8	60·2	59·2	59·5	51·6	53·9	58·2	58·6	58·0	58·0	51·8	52·5
150	57·3	58·8	58·0	58·4	52·1	53·7	56·8	57·8	56·5	57·0	51·3	52·1
165	56·5	58·2	57·0	57·8	52·5	53·5	56·1	57·0	55·9	56·5	51·3	52·1
180	55·7	57·0	55·9	56·5	52·3	53·7	55·0	56·5	54·7	55·7	51·1	52·1
195	55·0	57·0	54·3	56·5	51·3	54·3	54·7	55·9	54·3	55·5	50·7	52·1
225	54·3	56·1	53·9	56·1	51·3	53·9	54·1	55·7	53·9	55·0	50·9	52·1
255.	53·9	55·7	54·3	55·3	50·5	52·5	53·5	55·3	53·5	54·7	50·3	51·8

RELATIVE HUMIDITY.

Expt. Ref. FIRE OFF; HOPPER CLOSED

DAY 1

Pos.	I_1	I_2	I_3	II_1	II_2	II_3
0	77.0	83.0	71.0	72.0	75.0	76.0
15	77.0	84.0	72.0	72.0	76.0	76.0
30	77.0	82.0	72.0	71.0	74.0	76.0
45	80.0	80.0	78.0	77.0	80.0	79.0
60	83.0	82.0	77.0	77.0	82.0	86.0
75	88.0	83.0	80.0	81.0	86.0	86.0
90	96.0	88.0	80.0	97.0	90.0	94.0
105	100.0	93.0	79.0	96.0	93.0	91.0
120	91.0	97.0	82.0	97.0	100.0	89.0
135	89.0	94.0	81.0	92.0	97.0	86.0
150	88.0	91.0	83.0	89.0	92.0	86.0
165	87.0	91.0	83.0	89.0	92.0	89.0
180	87.0	92.0	84.0	88.0	91.0	89.0
195	87.0	91.0	85.0	87.0	91.0	88.0
225	88.0	90.0	85.0	84.0	90.0	87.0
255	85.0	90.0	86.0	80.0	88.0	88.0

DAY 2

Pos.	I_1	I_2	I_3	II_1	II_2	II_3
0	74.0	82.0	71.0	70.0	78.0	78.0
15	75.0	81.0	71.0	67.0	77.0	77.0
30	74.0	82.0	71.0	70.0	75.0	77.0
45	83.0	77.0	72.0	77.0	78.0	81.0
60	79.0	79.0	78.0	79.0	80.0	83.0
75	82.0	82.0	77.0	81.0	85.0	83.0
90	94.0	82.0	77.0	95.0	90.0	90.0
105	98.0	89.0	80.0	97.0	93.0	90.0
120	88.0	96.0	82.0	94.0	94.0	88.0
135	88.0	96.0	83.0	90.0	92.0	87.0
150	88.0	97.0	82.0	88.0	90.0	85.0
165	88.0	93.0	81.0	86.0	90.0	86.0
180	88.0	92.0	83.0	84.0	89.0	86.0
195	87.0	90.0	85.0	86.0	90.0	81.0
225	84.0	90.0	84.0	83.0	88.0	85.0
255	83.0	88.0	82.0	80.0	88.0	81.0

DAY 3

Pos.	I_1	I_2	I_3	II_1	II_2	II_3
0	73.0	82.0	69.0	73.0	77.0	72.0
15	73.0	81.0	69.0	74.0	77.0	75.0
30	73.0	82.0	69.0	70.0	75.0	74.0
45	84.0	79.0	73.0	80.0	85.0	81.0
60	85.0	81.0	78.0	81.0	86.0	85.0
75	86.0	81.0	78.0	82.0	90.0	82.0
90	87.0	84.0	76.0	90.0	88.0	85.0
105	98.0	90.0	92.0	99.0	98.0	99.0
120	100.0	100.0	89.0	98.0	100.0	89.0
135	90.0	97.0	87.0	94.0	97.0	88.0
150	88.0	93.0	81.0	90.0	96.0	88.0
165	88.0	92.0	80.0	89.0	92.0	88.0
180	86.0	92.0	84.0	89.0	93.0	85.0
195	88.0	92.0	81.0	88.0	95.0	85.0
225	85.0	91.0	83.0	82.0	90.0	87.0
255	82.0	92.0	79.0	85.0	90.0	83.0

DAY 4

Pos.	I_1	I_2	I_3	II_1	II_2	II_3
0	83.0	93.0	81.0	81.0	84.0	82.0
15	86.0	91.0	82.0	80.0	84.0	80.0
30	82.0	89.0	82.0	88.0	80.0	80.0
45	89.0	80.0	81.0	88.0	83.0	87.0
60	87.0	80.0	80.0	87.0	87.0	90.0
75	88.0	83.0	82.0	90.0	89.0	91.0
90	97.0	99.0	87.0	99.0	90.0	96.0
105	100.0	92.0	90.0	100.0	94.0	98.0
120	100.0	100.0	90.0	100.0	100.0	99.0
135	91.0	99.0	88.0	98.0	100.0	97.0
150	91.0	98.0	91.0	94.0	98.0	96.0
165	90.0	95.0	93.0	95.0	97.0	95.0
180	92.0	96.0	92.0	91.0	92.0	94.0
195	89.0	88.0	82.0	92.0	92.0	91.0
225	89.0	87.0	85.0	91.0	92.0	92.0
255	89.0	95.0	88.0	89.0	92.0	91.0

Expt. Ref. FIRE OFF; HOPPER OPEN.

DAY 1

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	45.4	50.3	46.7	49.3	44.7	49.1	47.5	50.9	47.0	50.0	45.2	49.5
15	45.4	50.3	46.5	49.3	44.7	48.8	47.7	51.1	46.7	50.3	45.4	49.5
30	45.4	50.3	46.5	49.5	44.9	49.5	48.8	52.8	47.5	51.8	45.8	50.0
45	53.0	57.0	51.1	55.0	49.5	53.7	54.7	58.0	51.8	55.5	48.8	51.8
60	55.7	69.9	64.1	67.8	51.6	65.3	57.5	60.6	54.7	57.8	50.7	53.0
75	57.3	61.8	56.1	59.5	53.0	56.5	59.0	62.0	55.7	59.2	51.8	54.1
90	67.8	68.3	61.8	64.1	56.1	58.4	69.4	70.0	63.2	65.4	54.7	56.1
105	72.1	72.5	65.9	67.0	57.8	59.2	72.5	72.5	66.1	67.6	66.1	56.5
120	62.3	64.1	61.6	62.0	56.8	68.8	63.2	63.2	59.5	60.2	55.7	56.1
135	59.7	61.8	59.2	59.5	55.5	57.5	60.2	60.8	57.5	58.8	55.0	56.9
150	57.5	67.7	57.3	68.4	54.3	56.5	58.6	59.5	56.5	58.0	54.3	55.7
165	56.1	58.8	55.9	57.3	53.5	55.9	57.3	68.6	55.5	57.3	53.7	55.0
180	55.0	58.0	56.3	57.0	52.8	55.5	56.1	58.0	54.7	56.5	53.3	54.7
195	54.3	67.5	54.5	56.3	52.3	55.3	55.7	57.5	53.9	56.5	62.5	54.5
225	53.0	56.3	53.3	55.3	51.1	54.3	54.5	56.8	53.0	55.7	52.1	54.3
255	52.1	65.9	52.5	54.5	60.5	53.7	53.7	55.9	52.1	55.0	51.1	53.9

Expt. Ref. h.

DAY 2

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	48.8	52.1	49.5	51.8	47.0	51.3	48.6	52.8	49.1	52.3	47.7	51.8
15	48.6	52.1	49.3	52.1	47.0	51.3	48.4	53.0	49.3	52.5	47.9	52.1
30	48.6	52.1	49.3	52.1	47.5	51.8	49.7	54.3	49.7	53.5	48.1	52.5
45	55.0	58.0	53.0	56.8	51.3	55.5	56.5	58.8	53.5	56.5	50.7	53.9
60	57.8	61.1	55.7	59.2	53.7	57.3	58.0	61.6	55.7	58.8	52.5	55.[illegible]
75	59.7	63.5	67.5	61.3	54.7	58.4	60.2	63.9	57.8	60.4	53.7	55.9
90	67.8	68.7	62.3	65.2	56.1	59.2	69.2	70.0	63.9	65.7	55.0	56.8
105	72.5	73.9	66.5	68.3	59.0	62.0	73.4	73.7	67.0	68.1	57.8	58.4
120	63.2	64.7	62.5	63.5	58.2	60.4	63.9	64.1	60.6	61.6	57.0.	58.4
135	60.4	62.7	60.2	61.1	56.8	58.8	61.1	62.3	58.6	60.4	56.3	58.0
150	59.0	61.3	58.4	59.7	55.7	58.4	59.2	61.1	57.5	59.2	55.9	57.8
165	57.5	60.2	57.3	58.8	54.7	57.5	57.8	59.9	56.5	58.8	54.7	57.0
180	56.8	59.5	56.5	58.2	53.9	57.0	57.3	59.5	56.1	58.4	54.3	56.8
195	56.1	58.8	55.9	57.8	53.3	56.5	56.3	58.8	55.3	57.5	54.1	56.5
225	55.0	57.8	54.7	57.0	52.5	55.9	55.3	58.0	54.3	56.5	53.0	55.9
255	54.5	57.3	54.3	56.5	52.1	55.5	54.5	57.5	53.9	56.3	52.5	55.5

Expt. Ref. n.

DAY 3.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	44.0	48.4	45.4	48.4	43.1	48.1	44.9	49.6	44.7	48.6	44.2	48.4
15	44.2	48.4	45.2	48.1	42.8	48.4	44.7	49.5	44.2	48.6	44.2	48.1
30	44.2	47.7	45.4	48.4	43.5	48.4	46.1	50.9	45.8	50.5	44.4	48.6
45	51.1	54.1	50.0	53.9	47.9	51.8	51.6	55.3	50.3	54.1	47.5	50.7
60	53.9	57.3	53.0	56.5	50.0	53.5	53.6	57.5	52.1	55.7	48.8	51.6
75	56.1	59.5	55.0	58.6	51.3	56.0	56.5	59.7	54.3	57.5	50.5	52.8
90	62.7	64.5	59.0	61.8	54.3	56.3	65.9	67.0	60.6	62.3	53.5	54.5
105	69.4	69.8	64.1	65.7	55.9	57.8	70.0	71.3	64.1	65.2	54.5	55.5
120	61.6	62.6	60.2	60.6	55.7	57.3	62.0	62.0	58.0	58.8	54.1	56.0
135	58.0	59.9	57.5	58.6	53.9	56.3	58.6	59.5	55.9	57.5	53.7	54.6
160	56.3	58.4	56.1	57.3	53.5	55.7	56.8	58.2	54.7	56.5	53.0	54.3
165	55.0	57.3	54.7	66.3	52.1	55.0	55.3	57.3	53.9	55.9	52.5	54.3
180	54.1	56.8	54.3	56.1	51.6	54.5	54.3	56.8	53.0	55.5	52.1	54.1
195	53.5	56.3	53.6	55.5	51.1	54.3	53.7	56.1	52.5	55.3	52.1	53.7
225	52.8	56.1	53.0	55.3	50.5	54.1	53.0	55.7	52.1	54.7	51.6	53.5
255	52.1	55.3	52.3	54.5	49.7	53.5	52.1	55.0	51.3	54.3	50.7	53.0

Expt. Ref. h.

DAY 4.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	41.5	44.0	42.4	44.4	41.5	44.2	42.4	44.9	42.4	44.7	41.9	44.7
15	42.1	44.7	43.3	44.9	41.9	44.7	42.8	45.4	42.6	44.9	42.4	45.2
30	42.6	45.2	43.5	45.6	42.4	45.2	44.0	47.0	44.0	46.7	42.8	45.6
45	48.8	51.3	47.5	50.9	45.8	48.6	48.8	51.3	47.9	50.5	45.4	47.5
60	51.3	53.9	49.7	53.5	47.9	50.3	51.1	53.7	50.3	52.8	46.6	48.4
75	53.5	56.1	51.8	55.3	49.1	51.6	53.3	55.5	52.1	54.3	47.9	49.5
90	57.5	59.2	55.0	57.6	50.9	53.0	60.6	61.3	56.8	58.2	49.7	50.9
105	65.2	66.2	60.4	62.3	52.8	53.9	65.9	66.8	60.8	61.6	51.1	52.1
120	56.1	57.3	56.6	57.0	52.5	53.9	55.3	55.5	54.7	54.7	51.1	51.8
135	53.0	54.7	54.1	54.7	51.3	53.0	52.5	52.9	52.1	53.5	50.7	51.1
150	52.3	54.3	53.0	54.1	50.7	52.3	51.8	53.5	51.8	53.0	50.3	51.1
165	51.1	53.7	52.1	53.3	50.0	51.8	50.7	52.8	50.7	52.3	49.7	50.9
180	50.3	52.5	51.3	52.8	49.7	51.6	50.0	52.3	50.0	52.1	49.7	50.7
195	49.7	52.3	50.7	52.1	48.8	51.1	49.5	52.1	49.7	51.6	49.3	50.5
225	48.8	51.6	49.5	51.1	47.7	50.5	49.3	51.6	48.8	51.1	48.1	50.0
255	48.6	51.6	49.3	51.3	47.7	50.3	48.8	51.6	48.4	50.9	47.9	50.3

RELATIVE HUMIDITY.

Expt. Ref. FIRE OFF; HOPPER OPEN

DAY 1.

Pos	I_1	I_2	I_3	II_1	II_2	II_3
0	69.0	82.0	70.0	79.0	80.0	73.0
15	69.0	81.0	70.0	78.0	78.0	74.0
30	69.0	80.0	70.0	77.0	74.0	78.0
45	78.0	79.0	77.0	80.0	79.0	81.0
60	78.0	80.0	79.0	82.0	82.0	88.0
75	77.0	81.0	80.0	84.0	80.0	87.0
90	98.0	88.0	88.0	98.0	89.0	91.0
105	99.0	94.0	92.0	100.0	92.0	99.0
120	90.0	99.0	89.0	100.0	96.0	98.0
135	89.0	99.0	89.0	98.0	92.0	96.0
150	88.0	94.0	88.0	96.0	91.0	92.0
165	86.0	91.0	87.0	92.0	90.0	91.0
180	82.0	90.0	84.0	90.0	90.0	91.0
195	81.0	90.0	81.0	90.0	84.0	89.0
225	81.0	89.0	81.0	88.0	84.0	89.0
255	79.0	89.0	80.0	88.0	84.0	85.0

DAY 2

Pos	I_1	I_2	I_3	II_1	II_2	II_3
0	79.0	86.0	72.0	76.0	80.0	75.0
15	78.0	81.0	72.0	72.0	81.0	73.0
30	78.0	81.0	73.0	72.0	77.0	74.0
45	88.0	79.0	77.0	81.0	82.0	88.0
60	81.0	80.0	79.0	80.0	82.0	86.0
75	80.0	80.0	79.0	81.0	87.0	88.0
90	95.0	85.0	82.0	96.0	90.0	89.0
105	94.0	90.0	84.0	98.0	94.0	91.0
120	92.0	95.0	89.0	99.0	94.0	87.0
135	89.0	95.0	89.0	94.0	90.0	90.0
150	88.0	92.0	86.0	89.0	90.0	89.0
165	85.0	91.0	84.0	89.0	88.0	87.0
180	85.0	90.0	81.0	88.0	88.0	86.0
195	85.0	89.0	81.0	87.0	88.0	87.0
225	84.0	86.0	80.0	85.0	88.0	83.0
255	84.0	88.0	80.0	83.0	85.0	82.0

DAY 3.

Pos.	I_1	I_2	I_3	II_1	II_2	II_3
0	78.0	80.0	69.0	70.0	74.0	72.0
15	80.0	80.0	62.0	69.0	72.0	74.0
30	77.0	80.0	69.0	71.0	70.0	72.0
45	82.0	78.0	77.0	79.0	78.0	80.0
60	80.0	80.0	80.0	78.0	80.0	82.0
75	81.0	80.0	79.0	82.0	82.0	87.0
90	90.0	85.0	89.0	94.0	91.0	94.0
105	98.0	91.0	89.0	93.0	95.0	94.0
120	96.0	98.0	90.0	100.0	96.0	96.0
135	90.0	93.0	86.0	95.0	90.0	94.0
150	89.0	94.0	88.0	91.0	90.0	92.0
165	87.0	90.0	83.0	89.0	89.0	90.0
180	85.0	89.0	82.0	86.0	86.0	89.0
195	84.0	88.0	81.0	85.0	84.0	91.0
225	80.0	84.0	79.0	84.0	85.0	89.0
255	81.0	87.0	78.0	83.0	82.0	87.0

DAY 4

Pos.	I_1	I_2	I_3	II_1	II_2	II_3
0	81.0	87.0	81.0	82.0	83.0	80.0
15	83.0	90.0	80.0	81.0	83.0	80.0
30	82.0	85.0	81.0	80.0	81.0	80.0
45	84.0	80.0	80.0	84.0	83.0	86.0
60	85.0	78.0	84.0	86.0	86.0	88.0
75	85.0	79.0	85.0	88.0	88.0	89.0
90	90.0	86.0	88.0	97.0	91.0	92.0
105	100.0	90.0	94.0	95.0	96.0	95.0
120	94.0	97.0	91.0	99.0	100.0	97.0
135	90.0	98.0	90.0	92.0	92.0	98.0
150	89.0	92.0	90.0	90.0	92.0	95.0
165	86.0	93.0	89.0	89.0	91.0	92.0
180	88.0	91.0	89.0	87.0	87.0	93.0
195	84.0	91.0	85.0	84.0	89.0	92.0
225	81.0	90.0	82.0	87.0	85.0	90.0
255	81.0	88.0	83.0	82.0	86.0	84.0

Expt. Ref. FIRE ON. HOPPER CLOSED.

DAY 1.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	47.2	51.3	48.1	50.6	44.2	48.8	48.0	52.5	48.4	52.5	46.1	49.5
15	47.7	51.8	48.4	50.7	44.7	49.1	49.3	52.8	49.1	53.0	46.1	49.5
30	47.9	52.3	48.6	51.3	46.4	49.7	51.3	55.7	50.9	55.5	47.0	50.9
45	54.3	580	52.8	56.5	50.0	53.7	56.1	59.5	55.3	59.0	49.1	52.5
60	57.0	61.6	55.9	59.7	51.3	56.9	58.8	63.2	58.2	62.7	50.0	53.7
75	59.7	64.5	58.4	62.3	52.8	57.3	60.8	65.4	59.7	64.1	51.1	53.9
90	67.2	68.7	62.7	66.9	55.3	58.2	69.6	70.8	66.5	68.5	53.5	55.0
105	71.9	72.1	67.6	70.0	56.3	59.7	73.7	73.4	69.6	71.3	54.3	56.1
120	64.1	67.4	63.9	64.9	56.1	59.2	63.9	65.7	62.5	64.9	53.7	56.3
135	60.6	64.5	61.1	62.5	55.9	58.6	61.6	64.3	61.3	64.5	53.3	56.1
150	59.7	63.9	59.7	62.0	55.7	58.6	60.8	64.5	61.6	65.7	53.3	56.5
165	58.8	62.9	58.8	61.1	54.7	58.0	59.7	63.7	59.7	64.1	52.5	55.9
180	58.0	62.5	58.0	60.6	54.3	58.0	59.2	63.5	59.5	63.7	52.	55.9
195	58.0	62.9	58.0	60.8	54.1	58.2	59.7	64.3	59.9	64.9	52.1	56.3
225	58.4	63.9	58.2	61.0	54.1	58.2	59.7	64.5	59.5	64.9	52.1	66.3
255	58.2	64.5	58.0	60.8	53.5	58.8	59.9	65.7	59.7	66.1	51.8	56.5

Expr. Ref: F.

DAY 2

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	53.9	59.2	55.0	58.6	51.8	56.5	54.7	60.2	54.7	60.2	51.8	56.8
15	53.7	59.2	55.3	68.6	51.6	56.8	55.0	60.6	55.3	60.6	51.2	57.0
30	55.5	61.1	56.3	60.6	53.0	58.6	58.2	64.1	580	63.7	53.7	58.4
45	60.8	66.3	60.8	65.2	56.8	62.3	62.3	67.8	61.8	67.0	55.5	59.9
60	63.7	69.2	63.7	67.8	58.4	63.9	64.3	70.0	63.9	68.7	56.3	60.4
75	66.3	71.5	66.1	69.8	59.7	64.9	67.4	72.3	66.3	71.0	57.5	61.1
90	75.9	77.0	72.7	74.8	63.2	67.4	78.2	78.5	76.1	76.3	60.4	62.3
105	79.5	80.3	76.8	78.2	63.2	68.5	80.9	81.8	77.7	78.5	62.3	64.3
120	70.8	75.7	71.0	72.9	64.1	67.8	71.0	75.1	70.0	75.1	61.1	64.3
135	68.5	73.4	68.5	71.3	63.7	67.4	68.7	73.7	68.7	73.9	60.6	64.5
150	67.0	72.7	67.6	70.6	63.2	67.0	68.1	72.9	68.1	73.7	60.2	64.3
165	66.3	72.7	67.0	70.6	63.2	66.8	67.4	73.2	67.2	72.9	59.9	64.3
180	66.1	73.4	66.8	70.8	62.9	67.0	67.6	74.1	67.2	73.9	59.9	64.9
195	66.1	74.3	67.2	71.7	62.5	67.6	67.4	75.1	67.2	75.1	60.2	65.4
225	65.9	74.1	67.0	71.9	62.3	67.0	67.4	75.5	67.0	75.7	60.4	65.7
255	65.7	74.3	66.8	71.7	61.8	67.0	67.6	75.7	67.4	76.3	59.7	66.1

Expt. Ref. F.

DAY 3

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	N. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	49·1	55·7	50·3	54·3	45·2	50·7	50·3	56·8	50·9	57·0	46·3	51·1
15	49·3	55·7	50·3	54·3	45·6	50·9	51·1	57·0	52·1	57·5	46·3	51·3
30	49·3	56·5	50·7	55·0	46·1	52·1	52·1	58·8	52·5	58·8	47·9	52·5
45	56·5	60·8	56·0	59·9	50·7	55·3	56·8	62·5	56·1	61·8	49·5	53·5
60	57·0	63·5	57·0	62·0	52·5	56·3	58·8	64·7	58·0	63·9	50·3	53·9
75	59·7	65·7	59·7	64·3	54·1	57·8	61·3	67·4	60·2	65·4	51·1	54·5
90	68·1	70·3	64·5	68·5	56·1	59·5	71·3	71·9	67·0	69·4	63·5	55·5
105	73·4	74·1	69·4	72·1	58·4	61·1	74·6	75·3	70·0	71·9	54·5	56·1
120	67·6	71·0	66·8	68·7	58·2	61·1	65·2	69·6	64·5	68·7	56·0	58·0
135	64·3	68·5	64·1	66·5	57·3	60·4	63·6	68·3	63·5	68·3	54·7	57·8
150	62·5	67·2	62·3	65·7	56·8	59·5	62·0	67·8	62·5	67·8	54·7	57·5
165	61·3	67·0	61·6	65·2	56·5	59·5	61·8	67·4	61·8	67·8	54·3	57·5
180	60·4	67·0	60·8	64·9	60·3	59·2	61·3	67·8	62·0	68·3	63·9	58·0
195	60·2	67·6	60·8	65·4	65·7	59·7	61·3	68·5	61·8	68·3	53·7	57·8
225	69·5	67·2	60·2	64·5	55·3	59·7	60·2	67·8	60·2	67·6	63·3	57·5
255	58·6	67·0	59·7	64·3	54·5	59·5	60·6	68·5	60·0	68·9	53·7	57·8

Expt. Ref. F.

DAY 4.

Pos	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	49.5	54.3	49.5	53.5	46.1	50.3	51.1	56.7	51.1	56.5	46.1	51.1
15	50.3	55.3	50.3	54.1	46.5	50.7	52.1	56.8	52.1	57.8	47.0	61.8
30	50.5	55.5	50.9	54.7	47.2	51.8	53.7	59.2	53.5	59.7	48.4	53.0
45	56.6	60.2	54.7	59.5	51.3	55.0	58.2	62.9	57.0	62.5	49.7	53.9
60	58.8	63.2	57.3	62.3	53.3	56.8	59.9	64.9	59.0	62.9	50.6	64.3
75	60.8	66.4	59.0	63.9	54.7	58.2	61.8	67.2	60.4	65.7	51.6	55.3
90	65.4	68.1	61.8	66.5	56.3	59.2	69.2	71.3	66.3	69.2	53.6	55.9
105	72.9	73.7	67.8	71.9	58.0	61.8	74.6	75.5	71.0	72.7	56.7	57.6
120	65.4	69.6	64.3	67.0	57.3	60.2	65.2	68.9	64.3	68.5	54.6	57.5
135	62.9	67.6	62.5	65.2	57.5	59.9	63.7	68.1	62.9	67.8	64.3	58.0
150	62.3	66.5	61.8	64.7	57.0	59.2	62.7	67.6	61.8	67.8	54.1	58.0
165	60.6	66.1	61.1	64.3	56.5	59.2	62.7	67.4	62.3	67.4	53.9	58.0
180	60.6	65.4	60.6	64.1	56.3	59.2	62.0	67.2	62.0	67.4	53.9	58.2
195	60.2	65.7	60.2	64.1	56.1	59.2	61.6	67.6	61.3	67.6	53.9	58.4
225	59.9	66.3	59.9	64.3	55.7	59.0	61.3	67.6	60.8	67.4	53.5	58.2
255.	59.7	66.8	69.7	64.5	55.7	59.2	62.0	68.7	61.1	68.3	53.7	58.4

RELATIVE HUMIDITY

Expt. Ref. FIRE ON; HOPPER CLOSED.

DAY 1

POS.	I_1	I_2	I_3	II_1	II_2	II_3
0	76.0	85.0	70.0	77.0	75.0	79.0
15	75.0	84.0	71.0	79.0	78.0	79.0
30	73.0	82.0	76.0	75.0	73.0	77.0
45	80.0	79.0	79.0	81.0	80.0	80.0
60	76.0	79.0	74.0	79.0	78.0	79.0
75	77.0	80.0	75.0	78.0	78.0	84.0
90	92.0	84.0	83.0	94.0	90.0	91.0
105	93.0	89.0	81.0	100.0	92.0	90.0
120	84.0	96.0	83.0	90.0	89.0	85.0
135	80.0	93.0	83.0	86.0	84.0	84.0
160	79.0	88.0	82.0	81.0	80.0	82.0
165	79.0	87.0	80.0	80.0	78.0	81.0
180	77.0	86.0	79.0	78.0	79.0	79.0
195	76.0	85.0	78.0	77.0	76.0	78.0
225	73.0	86.0	78.0	76.0	74.0	78.0
255	70.0	85.0	71.0	71.0	69.0	74.0

DAY 2.

I_1	I_2	I_3	II_1	II_2	II_3
71.0	80.0	73.0	70.0	70.0	72.0
71.0	81.0	71.0	70.0	71.0	69.0
71.0	78.0	70.0	71.0	71.0	74.0
73.0	79.0	71.0	76.0	76.0	78.0
75.0	81.0	73.0	75.0	78.0	79.0
78.0	83.0	74.0	79.0	79.0	80.0
94.0	90.0	81.0	99.0	95.0	90.0
97.0	94.0	77.0	97.0	96.0	90.0
79.0	91.0	82.0	82.0	78.0	84.0
79.0	88.0	82.0	79.0	77.0	80.0
75.0	87.0	82.0	79.0	76.0	80.0
72.0	83.0	88.0	75.0	76.0	78.0
69.0	82.0	80.0	72.0	72.0	76.0
66.0	80.0	78.0	69.0	68.0	75.0
65.0	78.0	79.0	67.0	64.0	75.0
63.0	79.0	76.0	67.0	64.0	68.0

DAY 3.

POS.	I_1	I_2	I_3	II_1	II_2	II_3
0	63.0	78.0	66.0	65.0	66.0	69.0
15	64.0	78.0	68.0	69.0	71.0	68.0
30	60.0	77.0	64.0	64.0	67.0	71.0
45	71.0	73.0	74.0	70.0	71.0	77.0
60	68.0	73.0	79.0	71.0	71.0	79.0
75	71.0	77.0	80.0	71.0	76.0	80.0
90	90.0	81.0	81.0	98.0	89.0	89.0
105	97.0	88.0	85.0	97.0	91.0	90.0
120	85.0	90.0	84.0	80.0	80.0	87.0
135	80.0	89.0	83.0	70.0	78.0	82.0
150	78.0	83.0	85.0	73.0	76.0	83.0
165	73.0	82.0	83.0	74.0	72.0	81.0
180	69.0	80.0	83.0	70.0	71.0	77.0
195	66.0	78.0	79.0	67.0	70.0	78.0
225	64.0	79.0	77.0	65.0	67.0	77.0
265	60.0	77.0	73.0	64.0	63.0	78.0

DAY 4

I_1	I_2	I_3	II_1	II_2	II_3
72.0	77.0	73.0	75.0	70.0	69.0
71.0	78.0	72.0	74.0	71.0	70.0
71.0	78.0	71.0	70.0	68.0	73.0
80.0	73.0	80.0	77.0	71.0	76.0
78.0	75.0	80.0	76.0	80.0	78.0
79.0	76.0	80.0	75.0	88.0	79.0
87.0	78.0	83.0	90.0	87.0	87.0
97.0	81.0	80.0	97.0	92.0	90.0
80.0	87.0	84.0	83.0	80.0	82.0
78.0	87.0	87.0	80.0	78.0	80.0
80.0	86.0	88.0	78.0	71.0	79.0
73.0	85.0	83.0	79.0	73.0	77.0
77.0	82.0	82.0	76.0	73.0	76.0
74.0	80.0	81.0	71.0	70.0	76.0
69.0	78.0	81.0	70.0	68.0	74.0
67.0	77.0	80.0	70.0	68.0	73.0

Expt. Ref. FIRE ON; HOPPER OPEN.

DAY 1

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	53.6	57.0	54.3	56.7	52.1	64.7	54.1	57.6	55.5	57.5	62.8	55.9
15	53.3	56.5	54.1	56.1	52.1	54.7	54.1	57.5	56.3	57.5	52.8	55.7
30	53.5	56.8	54.3	56.3	52.5	56.5	54.7	58.6	56.1	59.2	53.7	57.0
45	58.2	62.5	58.0	61.6	56.7	59.2	58.6	62.9	59.2	62.7	55.7	58.6
60	59.5	64.9	59.9	63.7	57.6	61.1	59.9	64.7	60.8	64.7	56.8	59.5
75	60.6	66.1	61.1	64.9	58.4	62.3	61.1	65.7	61.8	65.9	57.5	60.4
90	68.9	70.0	67.0	69.2	62.5	64.9	70.6	71.7	68.5	70.2	60.8	62.0
105	71.3	72.9	69.4	71.7	64.5	66.5	73.2	74.1	71.5	72.7	62.7	63.9
120	61.1	65.7	64.1	65.7	61.3	64.7	63.9	66.8	64.9	67.0	60.6	63.2
135	58.4	63.2	61.8	64.1	57.2	63.5	62.3	66.7	62.9	65.9	59.6	62.6
150	57.8	62.7	60.6	63.2	58.4	62.9	61.8	65.9	62.3	65.7	59.0	62.5
165	66.8	61.8	59.9	63.2	58.0	62.9	61.3	66.5	62.5	66.5	58.8	62.5
180	57.0	62.9	59.7	63.2	57.5	62.9	61.1	66.6	61.6	66.3	58.8	62.7
195	57.3	63.6	59.9	63.9	56.6	62.7	60.8	66.8	61.8	67.0	58.6	63.2
225	57.0	63.2	59.7	63.9	66.1	62.5	60.6	67.0	61.6	67.2	58.6	68.2
255	56.8	62.9	59.2	63.5	66.7	62.6	60.6	67.2	61.3	67.8	58.0	62.7

Expt. Ref. Fh.

DAY 2

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	51.1	65.3	64.3	56.1	50.0	64.5	53.3	68.0	64.3	68.6	50.5	54.5
15	49.5	53.9	52.8	65.3	49.6	54.3	63.0	68.4	53.9	58.4	50.7	54.7
30	50.5	55.3	53.0	66.1	50.5	55.9	64.5	69.9	66.3	60.6	61.6	55.7
45	56.3	60.8	56.5	60.4	54.5	69.0	68.4	63.7	58.6	68.9	54.1	57.3
60	59.7	64.6	68.8	62.7	56.1	60.8	60.6	66.1	60.2	65.9	55.3	58.6
75	60.6	66.1	60.4	64.1	57.3	62.3	62.5	67.6	61.3	67.0	56.1	58.8
90	68.3	70.0	64.9	67.4	61.3	64.3	71.7	72.9	67.0	69.6	59.7	61.3
105	73.2	73.7	69.2	70.8	64.5	67.2	73.4	74.1	68.9	70.6	61.3	62.5
120	61.8	64.9	61.8	63.7	60.2	63.9	68.2	66.1	62.9	66.9	58.4	61.1
135	60.4	63.5	60.2	62.7	58.4	62.7	61.8	66.1	61.6	65.7	57.8	61.1
150	58.0	61.6	68.8	62.0	57.3	62.3	60.6	66.7	60.4	65.2	56.5	61.1
165	68.2	63.5	58.6	61.8	56.3	62.3	60.2	65.9	59.7	65.2	66.1	61.1
180	57.0	62.9	58.2	61.8	65.9	62.0	60.4	66.1	69.7	66.4	55.9	60.6
195	56.9	62.0	58.4	62.3	65.7	62.3	69.7	66.9	69.2	65.7	66.6	61.1
225	53.9	59.9	57.5	61.8	64.7	62.0	69.6	67.0	59.5	67.0	55.3	61.1
255	57.0	64.3	57.5	62.0	54.3	61.8	68.6	66.1	68.4	65.9	54.7	61.3

Expt. Ref. Fh.

DAY3.

POS	I₁		I₂		I₃		II₁		II₂		II₃	
TIME.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	40.0	44.0	40.8	43.1	39.1	43.1	43.5	47.0	42.8	46.1	40.3	44.0
15	40.5	44.2	41.0	43.3	39.6	43.5	43.3	47.5	42.8	46.1	40.6	44.4
30	40.3	44.4	41.3	44.0	39.8	44.4	44.4	49.1	44.2	48.1	43.1	46.1
45	47.9	51.3	46.1	49.3	46.2	49.3	49.3	53.3	47.9	51.8	44.7	47.9
60	51.1	55.0	48.8	52.1	47.0	51.8	51.6	55.7	49.7	53.9	46.1	49.1
75	52.8	56.8	50.7	54.3	48.6	53.3	54.3	58.2	52.3	56.5	47.5	50.0
90	59.9	61.1	56.3	57.5	52.3	54.5	61.1	62.9	56.5	58.4	50.0	50.9
105	65.4	66.4	60.2	61.6	54.7	56.1	66.3	66.8	60.4	61.3	52.5	53.3
120	57.0	59.5	56.3	56.1	52.3	54.7	56.8	58.4	54.5	57.3	50.7	52.5
135	53.7	57.0	52.3	53.5	49.3	52.5	54.1	56.8	51.6	54.7	48.8	51.8
150	52.1	55.5	50.5	52.3	47.9	51.6	52.5	56.1	50.5	53.7	48.1	51.3
165	50.9	54.5	49.3	51.6	47.2	50.9	51.6	56.0	49.5	53.3	47.5	50.7
180	50.7	54.7	49.1	51.3	46.7	50.7	50.9	55.3	49.1	52.8	47.0	50.3
195	49.7	54.3	48.8	51.3	46.3	50.7	50.3	54.3	48.4	54.3	46.3	50.3
225.	47.9	53.0	47.2	50.3	45.2	49.5	50.5	54.3	47.9	52.3	45.6	49.7
255.	47.7	53.0	47.5	50.5	44.7	49.7	49.3	54.7	47.9	52.8	45.4	50.0

Expr. Ref. Fh.

DAY 4.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	N. B.	D. B.	W. B.	D. B.	W. B.	D. B	W. B.	D. B.	W. B.	D. B.
0	50.9	56.1	52.5	56.3	49.5	54.3	53.0	58.4	54.7	59.5	50.9	56.7
15	51.1	56.5	52.8	56.8	49.7	54.3	53.7	59.5	56.3	59.9	51.3	56.3
30	51.3	57.3	53.5	57.3	50.5	55.9	54.5	60.8	55.9	61.6	52.5	57.3
45	57.0	62.0	56.8	61.6	54.7	58.8	58.4	63.9	59.0	64.3	54.7	58.8
60	58.8	64.7	58.6	63.9	55.9	60.6	59.9	65.9	61.1	66.3	55.7	59.5
75	61.8	67.2	60.4	66.4	58.0	62.9	62.5	68.7	63.2	68.9	57.3	61.1
90	69.8	71.7	65.7	68.5	62.0	64.7	71.5	73.2	68.5	72.1	60.8	62.7
105	73.2	74.1	69.2	70.6	64.5	66.6	74.3	76.5	70.3	73.2	62.7	64.3
120	64.7	69.6	64.5	66.5	61.1	64.9	64.9	69.6	70.0	69.8	60.4	63.5
135	62.0	66.8	61.8	64.7	58.8	63.7	62.5	67.8	63.7	68.3	58.6	62.9
150	59.2	65.7	60.2	63.7	57.8	62.3	61.1	66.8	62.5	67.0	57.8	62.3
165	59.2	65.2	59.7	63.5	57.3	62.0	60.6	66.5	61.3	66.5	57.3	62.0
180	58.4	63.9	58.6	62.6	56.3	61.8	59.7	66.1	60.8	66.1	56.3	61.3
195	57.0	63.5	58.4	62.5	56.9	62.5	60.6	67.2	61.3	66.8	56.8	62.3
225	56.5	63.2	58.2	62.5	55.5	61.8	60.2	67.2	61.1	67.6	56.3	61.6
255	56.3	63.5	58.2	62.5	55.3	62.0	59.9	67.8	61.3	68.3	56.8.	62.0.

Expt. Ref. **RELATIVE HUMIDITY**

FIRE ON; HOPPER OPENED.

DAY 1

	I_1	I_2	I_3	II_1	II_2	II_3
0	80.0	91.0	84.0	80.0	89.0	81.0
15	82.0	89.0	84.0	80.0	88.0	82.0
30	81.0	88.0	78.0	79.0	83.0	80.0
45	79.0	80.0	80.0	79.0	81.0	80.0
60	74.0	80.0	80.0	76.0	80.0	84.0
75	73.0	81.0	80.0	79.0	80.0	85.0
90	93.0	89.0	88.0	94.0	91.0	94.0
105	93.0	90.0	90.0	96.0	96.0	94.0
120	79.0	92.0	82.0	85.0	89.0	88.0
135	75.0	88.0	79.0	83.0	84.0	84.0
150	74.0	86.0	77.0	80.0	83.0	81.0
165	78.0	82.0	76.0	76.0	80.0	80.0
180	70.0	81.0	72.0	75.0	79.0	79.0
195	70.0	80.0	69.0	73.0	76.0	76.0
225	69.0	80.0	69.0	70.0	73.0	76.0
255	69.0	79.0	67.0	69.0	70.0	76.0

DAY 2

	I_1	I_2	I_3	II_1	II_2	II_3
0	78.0	89.0	74.0	73.0.	75.0.	78.0
15	74.0	86.0	72.0	71.0.	74.0.	78.0
30	71.0	81.0	70.0	72.0.	72.0.	77.0
45	77.0	79.0	75.0	73.0.	73.0	81.0
60	77.0	79.0	75.0	73.0.	73.0.	81.0
75	74.0	81.0	76.0.	77.0.	73.0	85.0
90	92.0	88.0	85.0	94.0.	88.0	90.0
105	98.0	90.0	87.0.	97.0.	91.0	91.0
120	84.0	90.0	81.0.	86.0.	85.0	86.0
135	83.0	87.0	79.0.	79.0.	80.0	81.0
150	80.0	82.0	75.0.	76.0.	77.0	76.0
165	73.0	82.0	71.0.	72.0.	72.0	74.0
180	70.0	81.0	69.0	71.0.	71.0	74.0
195	69.0	80.0	67.0	70.0.	69.0	71.0
225	69.0	77.0	62.0.	64.0.	65.0	70.0
255	64.0	79.0	61.0.	62.0.	64.0.	66.0.

DAY 3.

	I_1	I_2	I_3	II_1	II_2	II_3
0	70.0	80.0	71.0	77.0	76.0	74.0
15	72.0	82.0	71.0	72.0	76.0	72.0
30	71.0	81.0	68.0.	70.0	74.0	72.0
45	79.0	80.0	73.0	78.0	76.0	79.0
60	79.0	80.0	70.0	78.0	76.0	80.0
75	78.0	78.0	71.0	78.0	77.0	84.0
90	92.0	88.0	88.0	91.0	90.0	94.0
105	100.0	92.0	91.0	98.0	96.0	100.0
120	85.0	94.0	88.0	91.0	83.0	89.0
135	80.0	93.0	80.0	85.0	82.0	81.0
150	80.0	90.0	77.0	79.0	81.0	80.0
165	78.0	86.0	78.0	80.0	78.0	80.0
180	78.0	87.0	75.0	74.0	79.0	79.0
195	72.0	84.0	71.0	78.0	67.0	75.0
225	69.0	83.0	73.0	78.0	72.0	79.0
255	68.0	81.0	68.0	70.0	69.0.	71.0.

DAY 4.

	I_1	I_2	I_3	II_1	II_2	II_3
0	70.0	78.0	71.0	69.0	74.0	72.0
15	70.0	77.0	73.0	69.0	76.0	72.0
30	68.0	78.0	70.0	67.0	70.0	72.0
45	74.0	74.0	77.0	72.0	73.0	78.0
60	71.0	73.0	74.0	70.0	76.0	79.0
75	74.0	77.0	76.0	72.0	74.0	79.0
90	90.0	88.0	87.0	92.0	83.0	90.0
105	96.0	92.0	90.0	95.0	87.0	91.0
120	77.0	89.0	81.0	78.0	100.0	84.0
135	77.0	86.0	75.0	76.0	79.0	79.0
150	69.0	82.0	78.0	73.0	79.0	77.0
165	71.0	80.0	76.0	72.0	76.0	76.0
180	73.0	80.0	71.0	69.0	75.0	74.0
195	68.0	79.0	64.0	69.0	73.0	71.0
225	67.0	77.0	67.0	67.0	70.0	72.0
255	64.0	77.0	66.0	68.0	68.0	73.0

Expt. Ref. FIRE OFF ; HOPPER CLOSED ; FAN ON.

DAY 1.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	55.9	59.9	51.3	59.7	50.9	58.6	53.7	60.6	53.8	59.7	51.8	58.4
15	55.9	60.2	50.9	59.7	50.3	58.0	53.3	60.8	52.8	59.7	51.3	58.0
30	55.3	60.6	51.3	60.2	50.7	58.4	53.9	61.8	53.5	60.6	51.6	58.6
45	58.4	64.3	55.0	63.2	52.1	60.4	56.8	64.7	55.9	62.9	52.1	59.2
60	60.2	66.1	56.5	64.9	53.0	61.1	58.2	66.5	57.3	64.1	52.5	59.7
75	62.3	68.1	58.0	66.5	53.7	61.8	60.4	68.1	59.2	65.7	53.7	60.4
90	68.1	71.9	63.2	68.7	54.7	62.7	69.8	72.7	66.1	68.3	55.3	61.1
105	71.0	73.7	65.9	70.6	55.7	62.9	71.3	73.2	67.2	69.4	56.1	61.6
120	67.4	69.6	61.6	68.1	54.5	62.0	64.3	68.7	61.8	66.5	54.7	61.1
135	63.9	67.4	58.6	66.1	53.3	61.8	59.2	66.8	59.0	64.9	54.3	61.1
150	61.3	66.1	56.8	65.2	52.8	61.3	57.0	65.7	57.5	64.1	53.7	60.6
165	60.6	65.7	56.3	64.5	51.8	61.1	56.3	65.2	56.5	63.5	53.0	60.6
180	59.5	65.2	55.3	64.1	51.3	60.4	55.7	64.9	55.7	63.5	53.0	60.6
195	59.2	64.7	55.3	63.9	51.6	60.2	55.7	64.5	55.5	62.9	53.0	60.2
225	58.8	64.7	55.3	63.9	51.8	60.2	55.5	64.7	55.3	62.9	53.0	60.2
255	58.6	64.3	55.0	63.5	51.6	59.7	56.0	64.3	54.7	62.7	52.5	59.9

Expt. Ref. f.

DAY 2

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	60.6	64.9	56.8	64.7	55.7	62.5	57.5	65.2	56.5	64.1	55.9	62.7
15	60.4	64.9	56.1	63.9	56.0	61.8	57.3	65.2	56.5	63.9	55.7	62.5
30	59.7	64.5	56.1	63.9	54.7	61.8	58.0	66.1	57.0	64.7	55.7	62.5
45	62.7	67.8	58.8	67.0	55.7	63.5	60.8	69.2	59.2	67.0	55.7	62.5
60	63.7	70.0	59.9	68.5	56.1	64.1	62.0	70.3	60.8	68.1	56.1	62.9
75	65.4	71.9	61.8	70.0	56.3	64.7	64.3	70.9	62.7	69.2	56.1	63.2
90	73.7	76.3	69.2	72.7	57.5	65.2	73.2	75.9	69.4	71.9	56.8	63.5
105	75.5	78.0	70.6	74.6	57.5	65.2	75.3	77.3	71.3	73.2	56.8	63.9
120	69.2	72.3	63.5	69.8	56.1	64.1	67.0	71.5	62.9	68.7	56.9	63.5
135	66.5	70.6	61.3	68.3	55.7	64.1	65.4	69.8	61.3	67.6	55.7	63.2
150	63.9	68.7	60.2	66.5	55.7	62.9	62.0	68.7	60.2	66.8	56.1	63.2
165	63.2	68.1	58.8	67.0	54.7	62.5	60.6	68.3	59.0	66.1	55.5	62.5
180	62.0	67.4	58.4	66.3	54.5	62.5	59.7	67.8	58.4	66.1	55.3	62.3
195	61.6	67.4	57.5	66.1	54.1	61.8	58.6	67.4	57.8	65.7	55.0	62.0
225	60.8	66.8	57.0	65.7	53.3	61.6	58.0	67.2	57.3	65.7	54.3	62.0
255	60.2	66.1	57.0	64.9	53.0	61.1	57.8	66.8	56.8	65.4	53.9	61.6

Expt. Ref. f.

DAY 3

POS	I₁		I₂		I₃		II₁		II₂		II₃	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	47.9	50.9	46.3	50.5	44.9	49.5	46.5	51.3	46.5	50.7	44.7	49.1
15	47.9	51.1	45.4	50.3	44.4	49.1	46.1	51.6	46.5	50.5	44.4	49.1
30	48.1	51.1	45.6	50.7	44.7	49.5	47.5	52.5	47.0	51.6	44.7	49.7
45	51.3	55.5	49.3	54.1	45.8	50.7	50.7	55.7	50.0	53.9	45.6	50.7
60	53.7	57.8	51.1	56.3	47.2	52.3	52.3	57.3	51.6	55.5	46.3	50.9
75	55.3	59.0	52.1	57.3	47.2	52.1	54.3	59.2	53.0	56.5	46.3	50.9
90	58.0	61.3	54.5	58.8	47.9	52.5	60.2	62.3	56.3	59.2	46.7	51.1
105	64.3	66.1	59.5	61.1	49.1	53.0	65.7	66.8	59.7	61.8	47.9	51.6
120	59.2	60.6	54.3	58.2	47.2	51.3	57.8	59.5	55.7	57.0	45.8	50.5
135	56.8	58.6	52.3	56.8	46.7	51.1	58.0	58.0	54.3	56.1	45.8	50.5
150	55.9	57.5	51.8	56.1	47.0	51.1	53.7	57.3	53.3	55.7	46.5	50.9
165	54.5	57.0	51.3	55.7	46.7	51.1	52.1	56.5	52.8	55.3	45.8	50.3
180	53.9	56.5	50.7	55.3	46.5	50.7	51.6	56.1	52.1	55.3	45.6	50.5
195	53.3	56.3	50.3	55.3	46.3	50.9	51.6	56.5	52.1	55.0	46.1	50.5
225	52.1	55.3	48.8	53.9	46.1	50.9	50.0	55.3	49.7	53.9	45.4	50.0
255	51.1	54.7	48.4	53.5	46.1	50.5	49.3	54.5	48.8	53.5	45.6	50.0

Expt. Ref. f.

DAY 4

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	47.2	50.5	46.1	50.3	45.4	49.7	46.5	50.9	46.3	50.3	46.1	49.7
15	47.5	50.7	46.3	50.5	45.2	49.7	46.3	51.1	46.3	50.5	46.3	50.0
30	47.9	51.3	47.0	50.9	45.6	50.3	47.6	52.1	47.2	51.3	46.3	50.5
45	50.9	55.0	49.7	54.1	46.5	51.6	50.7	55.3	50.0	53.9	47.2	51.6
60	52.8	56.5	51.3	55.5	47.5	52.5	52.1	56.5	51.3	55.0	47.0	50.7
75	54.7	58.8	53.0	57.0	47.5	52.5	54.3	58.4	50.3	56.3	47.2	51.8
90	60.2	62.5	56.5	59.9	48.6	53.3	62.0	63.2	57.8	59.7	47.5	51.6
105	63.9	65.2	59.2	61.3	49.3	54.1	64.7	65.2	59.9	61.3	47.7	52.1
120	58.8	60.6	57.3	59.0	50.5	53.7	57.3	58.8	55.9	57.5	47.9	52.5
135	57.0	59.0	54.5	57.8	48.6	53.0	56.1	58.2	55.5	56.8	48.4	53.3
150	54.6	57.3	53.0	56.5	47.2	52.3	54.3	57.3	54.3	56.1	47.2	52.5
165	53.9	56.8	51.8	56.1	47.2	52.1	53.5	56.8	53.7	56.1	47.0	52.1
180	53.0	56.5	51.6	56.1	47.0	52.1	52.5	56.1	53.0	55.5	47.0	52.1
195	53.0	56.5	51.8	55.9	47.2	52.5	51.6	55.9	53.0	55.3	46.5	52.1
225	52.3	56.3	51.1	55.7	47.0	52.5	53.0	56.5	53.5	55.7	47.5	52.8
255	52.5	56.8	51.8	56.1	47.5	53.3	50.7	56.1	50.5	55.3	47.2	52.5

RELATIVE HUMIDITY

Expt. Ref. FIRE OFF; HOPPER CLOSED; FAN ON.

DAY 1

	I_1	I_2	I_3	II_1	II_2	II_3
0	79.0	57.0	59.0	63.0	67.0	65.0
15	77.0	53.0	69.0	61.0	63.0	63.0
30	71.0	54.0	69.0	60.0	61.0	61.0
45	70.0	60.0	58.0	61.0	70.0	62.0
60	71.0	60.0	58.0	61.0	67.0	61.0
75	72.0	60.0	59.0	64.0	69.0	65.0
90	83.0	75.0	60.0	87.0	89.0	70.0
105	87.0	79.0	64.0	91.0	90.0	71.0
120	89.0	70.0	61.0	79.0	78.0	66.0
135	82.0	64.0	58.0	64.0	71.0	64.0
150	77.0	60.0	57.0	59.0	67.0	63.0
165	75.0	60.0	52.0	58.0	65.0	60.0
180	72.0	58.0	54.0	57.0	61.0	60.0
195	72.0	59.0	56.0	58.0	63.0	62.0
225	71.0	59.0	57.0	57.0	62.0	62.0
255	71.0	58.0	58.0	55.0	60.0	61.0

DAY 2.

	I_1	I_2	I_3	II_1	II_2	II_3
0	79.0	61.0	66.0	62.0	62.0	66.0
15	78.0	62.0	66.0	61.0	64.0	67.0
30	77.0	62.0	63.0	61.0	62.0	67.0
45	77.0	61.0	61.0	61.0	63.0	67.0
60	72.0	60.0	61.0	63.0	67.0	68.0
75	71.0	64.0	60.0	67.0	70.0	65.0
90	88.0	84.0	62.0	88.0	88.0	68.0
105	90.0	82.0	62.0	91.0	91.0	65.0
120	86.0	72.0	61.0	80.0	73.0	62.0
135	81.0	68.0	59.0	80.0	70.0	62.0
150	78.0	70.0	64.0	69.0	69.0	65.0
165	77.0	61.0	61.0	65.0	67.0	65.0
180	70.0	62.0	60.0	62.0	62.0	66.0
195	73.0	59.0	61.0	59.0	62.0	65.0
225	72.0	59.0	58.0	58.0	60.0	60.0
255	71.0	62.0	58.0	58.0	59.0	60.0

DAY 3

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	81.0	74.0	70.0	69.0	75.0	70.0
15	80.0	70.0	70.0	67.0	75.0	70.0
30	81.0	68.0	69.0	70.0	71.0	68.0
45	77.0	71.0	69.0	71.0	78.0	69.0
60	78.0	71.0	70.0	72.0	78.0	71.0
75	80.0	72.0	70.0	73.0	80.0	71.0
90	82.0	77.0	71.0	89.0	84.0	70.0
105	90.0	90.0	80.0	95.0	88.0	77.0
120	91.0	79.0	76.0	90.0	91.0	70.0
135	88.0	76.0	71.0	86.0	89.0	71.0
150	90.0	76.0	74.0	80.0	87.0	71.0
165	85.0	75.0	71.0	77.0	85.0	70.0
180	84.0	74.0	72.0	74.0	81.0	69.0
195	82.0	71.0	71.0	72.0	84.0	72.0
225	82.0	70.0	71.0	70.0	77.0	70.0
255	80.0	70.0	72.0	70.0	72.0	71.0

DAY 4.

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	80.0	75.0	72.0	72.0	75.0	78.0
15	80.0	74.0	71.0	70.0	74.0	77.0
30	79.0	77.0	70.0	71.0	75.0	74.0
45	77.0	74.0	69.0	74.0	78.0	72.0
60	80.0	77.0	70.0	77.0	79.0	78.0
75	78.0	78.0	70.0	78.0	68.0	71.0
90	88.0	81.0	71.0	94.0	90.0	76.0
105	93.0	89.0	71.0	98.0	92.0	72.0
120	90.0	91.0	80.0	91.0	90.0	71.0
135	89.0	81.0	73.0	88.0	91.0	71.0
150	84.0	80.0	70.0	82.0	89.0	69.0
165	82.0	76.0	70.0	80.0	86.0	69.0
180	80.0	74.0	69.0	79.0	86.0	69.0
195	80.0	78.0	69.0	77.0	87.0	66.0
225	78.0	75.0	68.0	80.0	87.0	68.0
255	77.0	76.0	67.0	69.0	73.0	68.0

Expt. Ref. FIRE OFF; HOPPER OPEN; FAN ON.

DAY 1

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B	D. B	W B	D B	W B	D B	W B	D B	W B	D B	W B	D B
0	46.3	53.3	48.6	53.0	45.2	52.1	45.6	53.9	46.3	53.0	46.7	52.5
15	45.2	52.5	48.1	52.8	45.2	52.1	45.6	53.9	46.1	53.0	47.0	52.8
30	45.2	52.5	47.9	53.0	45.2	52.1	46.1	54.3	46.5	53.9	47.2	53.3
45	48.1	55.9	50.3	56.1	47.5	54.7	48.4	56.5	48.6	55.7	47.5	54.5
60	50.7	58.2	51.8	57.8	48.4	55.7	50.3	58.2	50.5	57.3	47.5	54.5
75	52.3	59.2	53.0	58.6	48.8	56.5	52.1	59.2	51.8	58.6	48.6	55.0
90	55.7	61.3	56.1	60.6	50.5	57.5	59.2	62.0	57.5	60.6	50.7	56.1
105	62.0	63.9	60.2	63.2	54.1	58.8	62.9	64.3	60.4	62.3	53.0	56.8
120	53.3	58.8	56.5	59.5	62.1	57.8	53.7	59.0	53.5	58.4	50.5	56.8
135	50.5	57.5	54.1	58.0	50.5	57.3	50.5	58.0	50.7	57.0	49.7	56.5
150	49.3	57.3	53.0	57.5	49.3	57.0	49.7	57.5	49.7	57.0	49.1	56.3
165	49.5	57.5	52.5	57.8	49.3	57.0	49.7	58.0	50.0	57.0	48.8	56.5
180	48.8	57.0	52.3	57.3	48.6	56.5	49.5	57.8	49.3	57.0	48.8	56.3
195	48.8	57.0	52.3	57.5	48.4	56.5	49.3	58.0	49.3	57.0	48.4	56.5
225	49.1	57.5	52.3	57.5	48.1	56.5	49.3	58.2	49.3	57.3	48.1	56.5
255	48.1	57.3	52.1	57.5	47.9	58.8	49.5	58.6	49.3	57.8	48.4	56.5

Expt. Ref. f.h.

DAY 2

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME.	W B.	D B.	W B.	D B.	W B.	D B.	W B.	D B.	W B.	D B.	W B.	D B.
0	49.5	54.3	47.2	54.7	46.5	54.1	48.1	55.7	48.8	54.7	47.7	54.5
15	49.1	53.9	46.7	54.3	46.3	53.7	48.1	55.7	48.1	54.5	47.2	54.3
30	48.8	53.9	46.5	54.3	46.5	54.3	48.6	56.1	48.8	56.3	48.1	55.0
45	51.3	56.5	50.0	57.0	49.7	57.3	50.9	57.5	50.5	57.0	50.3	56.5
60	53.3	58.6	51.3	58.4	49.7	57.5	52.8	59.2	52.1	58.4	50.3	56.5
75	55.0	60.2	53.0	60.2	51.1	58.8	63.5	59.9	53.3	59.2	52.5	58.4
90	61.1	64.7	58.4	62.7	53.3	59.7	62.5	64.1	59.7	62.7	53.7	58.4
105	61.8	62.7	60.8	63.5	57.8	61.8	62.9	64.3	60.8	62.9	57.0	59.7
120	58.0	58.8	55.3	60.4	54.5	59.7	55.7	60.2	55.7	59.2	54.1	58.8
135	54.3	58.4	62.5	59.0	52.1	58.6	63.0	59.2	53.3	58.8	51.8	58.0
150	53.0	58.0	51.6	58.8	50.7	58.4	51.6	58.6	52.1	58.4	51.6	57.8
165	52.5	57.3	50.7	58.2	50.0	57.8	51.3	58.4	51.8	58.2	51.1	57.8
180	52.1	56.8	50.5	57.8	49.3	57.3	51.1	58.6	51.1	58.2	50.9	57.5
195	53.5	57.8	50.7	58.4	50.3	57.8	51.6	58.6	52.5	58.2	50.9	57.5
225	52.8	56.5	49.7	57.3	49.7	57.0	51.3	58.4	51.6	58.0	50.7	57.0
255	52.5	57.0	50.3	57.5	49.5	57.3	52.1	58.6	52.1	58.0	50.9	57.3

Expt. Ref. fh.

DAY 3

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	55.3	68.8	52.5	59.0	51.6	57.8	53.9	60.2	53.5	58.8	55.3	59.7
15	52.5	58.4	50.9	58.2	50.0	57.3	52.1	59.2	52.5	58.8	52.1	58.4
30	52.8	58.8	51.3	58.6	50.9	58.4	62.3	59.9	52.3	59.5	53.0	58.8
45	55.3	61.8	53.5	61.1	52.5	60.2	53.5	61.1	53.5	60.6	53.7	59.7
60	56.1	62.9	54.3	62.3	53.5	60.8	54.5	62.3	54.5	62.0	54.5	60.2
75	57.8	64.1	55.7	63.5	54.3	61.8	56.1	63.5	56.1	62.9	55.5	60.6
90	63.7	67.0	60.6	65.4	58.0	63.7	61.6	65.4	61.1	65.2	58.6	62.0
105	64.5	67.0	62.7	67.0	60.6	64.3	63.9	66.5	62.9	66.1	60.2	62.5
120	58.4	63.2	58.8	64.3	56.8	62.3	60.4	67.2	57.0	62.3	54.7	61.1
135	55.7	61.8	54.7	62.5	53.3	61.3	54.7	62.0	54.5	61.8	53.9	61.1
150	54.7	60.6	53.7	61.8	52.5	61.1	53.5	61.6	53.9	61.1	53.0	60.6
165	54.7	61.1	53.3	61.6	52.1	60.6	53.7	61.6	53.5	61.1	53.5	60.6
180	54.3	60.8	53.0	61.3	52.1	60.6	53.5	61.8	63.5	61.1	53.0	60.4
195	53.7	60.2	52.5	60.8	51.6	60.2	53.3	61.3	53.3	60.8	53.0	60.4
226	53.7	60.4	53.0	60.8	51.8	60.4	53.0	61.6	52.8	61.1	52.8	60.2
255	53.9	60.2	52.5	60.6	52.1	60.2	53.9	61.6	53.0	60.8	52.5	60.2

Expt. Ref. f. h.

DAY 4.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	49.1	52.1	48.6	52.1	47.9	51.8	48.8	52.5	49.1	52.1	48.8	52.1
15	49.1	51.8	48.6	52.1	47.9	51.8	48.6	52.8	49.1	52.3	48.8	52.1
30	50.0	53.0	49.3	52.8	48.8	53.0	50.0	53.9	50.0	53.7	49.7	53.5
45	53.0	56.3	52.1	55.5	50.7	54.5	52.1	55.9	52.1	55.0	50.9	54.3
60	55.0	58.4	53.7	57.6	51.1	55.7	53.9	57.5	53.7	57.0	51.6	55.0
75	55.7	58.8	54.3	58.2	52.8	56.8	54.7	58.0	54.5	57.8	52.5	55.3
90	60.2	61.3	58.4	60.4	54.3	57.8	61.1	62.0	59.5	61.3	54.3	56.1
105	63.5	64.7	61.8	62.7	56.1	58.8	62.9	63.7	61.6	62.5	55.7	56.5
120	55.9	57.6	56.1	58.6	54.7	57.0	55.7	57.5	55.7	57.0	54.5	56.3
135	54.7	56.8	54.5	57.5	53.0	56.5	54.1	56.8	54.1	56.1	53.3	55.7
160	53.5	55.7	53.3	56.3	52.1	55.7	53.0	55.9	53.3	55.9	52.8	55.1
165	52.5	55.3	52.5	56.1	51.6	55.5	52.5	55.9	52.5	55.7	52.3	55.3
180	52.1	55.0	52.1	55.7	50.9	55.0	51.8	55.7	51.8	55.3	51.6	55.0
195	51.3	54.7	51.8	55.5	50.7	54.7	51.1	55.3	51.6	55.0	51.1	54.7
225	51.0	54.5	51.1	56.3	49.7	54.7	50.7	55.3	51.1	54.5	50.7	54.5
255.	50.9	54.3	50.9	55.0	49.7	54.7	50.5	55.5	50.9	54.5	50.7	54.5

RELATIVE HUMIDITY.

Expt. Ref. FIREOFF; HOPPER OPEN; FAN ON.

DAY 1

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	59.0	73.0	59.0	58.0	60.0	65.0
15	58.0	72.0	59.0	52.0	60.0	66.0
30	58.0	69.0	59.0	53.0	58.0	64.0
45	58.0	68.0	59.0	57.0	60.0	60.0
60	59.0	68.0	59.0	68.0	63.0	60.0
75	63.0	70.0	58.0	63.0	63.0	64.0
90	71.0	77.0	61.0	85.0	82.0	69.0
105	90.0	84.0	75.0	92.0	90.0	79.0
120	71.0	82.0	70.0	71.0	73.0	66.0
135	62.0	79.0	63.0	60.0	64.0	61.0
150	57.0	75.0	58.0	58.0	60.0	61.0
165	57.0	71.0	58.0	56.0	61.0	58.0
180	56.0	71.0	58.0	56.0	59.0	59.0
195	56.0	71.0	56.0	54.0	68.0	56.0
225	56.0	71.0	55.0	52.0	57.0	55.0
255	53.0	70.0	51.0	51.0	55.0	56.0

DAY 2

I_1	I_2	I_3	II_1	II_2	II_3
72.0	58.0	57.0	59.0	67.0	61.0
72.0	57.0	58.0	59.0	64.0	60.0
70.0	60.0	60.0	58.0	63.0	61.0
71.0	61.0	59.0	63.0	64.0	67.0
70.0	62.0	58.0	67.0	67.0	67.0
72.0	62.0	60.0	68.0	69.0	69.0
82.0	79.0	67.0	90.0	83.0	75.0
96.0	87.0	79.0	92.0	90.0	85.0
96.0	73.0	71.0	77.0	80.0	75.0
78.0	66.0	67.0	68.0	70.0	67.0
72.0	61.0	59.0	61.0	68.0	67.0
73.0	59.0	58.0	62.0	66.0	64.0
74.0	60.0	57.0	60.0	62.0	64.0
76.0	60.0	60.0	62.0	69.0	64.0
80.0	59.0	60.0	62.0	66.0	65.0
75.0	61.0	58.0	65.0	69.0	64.0

DAY 3

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	80.0	66.0	67.0	67.0	71.0	77.0
15	69.0	60.0	60.0	62.0	67.0	68.0
30	68.0	61.0	60.0	60.0	62.0	69.0
45	68.0	60.0	60.0	60.0	59.0	68.0
60	67.0	60.0	61.0	60.0	61.0	69.0
75	69.0	64.0	62.0	64.0	67.0	72.0
90	84.0	78.0	71.0	81.0	80.0	81.0
105	88.0	80.0	81.0	87.0	84.0	89.0
120	77.0	72.0	71.0	68.0	72.0	67.0
135	68.0	60.0	60.0	63.0	62.0	62.0
150	69.0	59.0	57.0	59.0	61.0	60.0
165	67.0	59.0	57.0	60.0	60.0	62.0
180	67.0	58.0	57.0	58.0	60.0	62.0
195	66.0	59.0	57.0	59.0	61.0	62.0
225	65.0	60.0	57.0	57.0	55.0	61.0
255	67.0	59.0	59.0	60.0	60.0	60.0

DAY 4.

I_1	I_2	I_3	II_1	II_2	II_3
81.0	78.0	76.0	78.0	81.0	80.0
84.0	78.0	76.0	75.0	80.0	80.0
82.0	80.0	76.0	78.0	79.0	78.0
81.0	80.0	78.0	80.0	83.0	80.0
79.0	79.0	75.0	79.0	80.0	80.0
82.0	79.0	78.0	80.0	81.0	83.0
94.0	89.0	80.0	96.0	90.0	89.0
94.0	87.0	87.0	96.0	96.0	92.0
90.0	87.0	87.0	89.0	92.0	89.0
88.0	82.0	80.0	86.0	89.0	87.0
88.0	82.0	80.0	83.0	86.0	87.0
84.0	79.0	78.0	80.0	81.0	82.0
84.0	80.0	77.0	78.0	80.0	80.0
80.0	79.0	78.0	78.0	80.0	80.0
80.0	77.0	71.0	73.0	80.0	79.0
79.0	77.0	71.0	72.0	79.0	79.0

Expt. Ref. FIRE ON; HOPPER CLOSED; FAN ON.

DAY 1.

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	52.5	58.0	52.8	56.5	49.1	53.9	52.5	59.0	52.1	57.0	48.8	54.3
15	53.5	58.6	53.3	57.3	49.7	54.5	53.5	60.6	52.5	58.0	49.1	54.5
30	54.5	60.8	54.3	59.2	50.7	56.3	54.7	62.9	54.5	60.4	50.0	56.1
45	58.4	64.5	57.0	62.9	53.0	58.8	68.0	66.5	57.0	63.5	52.1	57.5
60	60.6	67.2	59.2	65.4	54.3	60.2	59.9	68.7	58.6	65.7	53.3	58.8
75	62.9	70.6	61.3	67.8	57.0	62.3	61.6	71.0	59.9	67.2	54.1	59.9
90	65.7	72.7	63.5	69.6	58.2	63.5	67.0	73.9	62.9	69.8	57.0	62.7
105	73.2	77.3	67.4	73.2	60.8	65.2	72.5	77.0	68.3	72.3	59.0	63.5
120	66.5	74.6	65.9	71.0	59.9	64.1	67.4	73.9	62.3	69.4	56.1	62.5
135	64.7	73.4	64.5	70.3	59.0	63.9	63.2	73.4	61.6	69.2	56.1	63.2
150	64.3	73.2	64.3	70.6	58.4	63.9	62.7	73.7	61.1	69.6	55.7	63.5
165	63.9	73.7	64.3	70.8	58.0	63.9	62.7	74.1	61.1	70.0	55.3	63.2
180	63.9	73.7	64.1	70.6	57.3	63.9	62.5	74.6	60.8	69.8	55.0	63.2
195	63.7	73.7	63.9	70.8	57.0	65.2	62.5	74.3	60.6	69.8	55.0	63.5
225	64.7	74.6	64.3	71.5	57.0	65.7	62.7	75.7	61.1	71.3	55.5	64.3
255	65.9	75.9	65.2	72.9	57.5	66.5	64.1	77.5	62.3	72.7	57.0	66.5

Expr. Ref. F.f.

DAY 2.

POS	I_1		I_2		I_3		II_1		II_2''		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	59.2	67.4	56.3	67.4	53.3	63.9	58.4	70.8	58.4	69.6	54.7	64.9
15	61.1	70.6	58.2	69.4	54.5	64.9	59.2	72.1	59.0	69.8	55.3	65.7
30	62.8	72.7	59.2	71.3	55.5	66.3	61.8	75.7	61.6	74.6	56.8	67.4
45	67.0	77.0	63.7	76.3	58.8	70.0	64.7	78.7	63.9	77.5	58.4	69.2
60	69.2	80.1	64.9	79.5	61.1	71.9	66.3	81.8	65.7	79.6	58.6	69.8
75	71.9	83.0	66.5	81.1	61.8	72.7	68.3	83.0	67.2	81.4	59.5	71.0
90	79.9	87.6	73.9	84.6	66.8	74.8	77.3	89.1	74.3	86.3	63.9	72.1
105	83.0	89.1	76.1	86.2	64.4	76.1	79.0	89.6	76.5	86.8	64.7	73.2
120	76.8	87.3	69.6	84.1	64.7	75.1	70.0	86.2	69.8	82.7	60.8	72.3
135	73.4	86.1	67.8	83.0	63.2	74.3	68.5	86.2	68.3	83.0	60.2	72.7
150	72.7	86.6	67.0	82.5	62.0	74.1	68.3	86.6	67.4	83.0	60.6	73.7
165	72.1	86.1	67.6	83.0	61.1	74.1	68.3	87.3	67.8	83.5	60.4	74.1
180	72.3	87.0	67.0	83.2	60.6	73.9	68.3	87.8	67.6	83.5	60.2	74.3
195	72.3	87.0	67.0	83.5	60.8	74.6	68.1	87.3	67.6	83.5	60.8	76.5
225	73.2	89.1	67.8	85.6	61.3	75.9	69.2	89.3	67.8	85.6	62.0	77.5
255	74.3	90.5	68.1	87.0	61.6	76.8	71.3	91.7	68.5	87.9	62.3	78.1

RELATIVE HUMIDITY.

Expt. Ref. FIRE ON, HOPPER CLOSED; FAN ON.

TIME	DAY 1. I_1	I_2	I_3	II_1	II_2	II_3	DAY 2. I_1	I_2	I_3	II_1	II_2	II_3
0.	70.0	78.0	72.0	65.0	73.0	68.0	62.0	50.0	50.0	48.0	60.0	62.0
15.	72.0	78.0	71.0	62.0	70.0	70.0	59.0	50.0	50.0	47.0	52.0	51.0
30.	68.0	73.0	69.0	60.0	69.0	67.0	57.0	49.0	50.0	47.0	48.0	61.0
45.	70.0	71.0	69.0	60.0	68.0	70.0	60.0	50.0	51.0	48.0	48.0	62.0
60.	69.0	70.0	69.0	59.0	67.0	70.0	58.0	45.0	55.0	45.0	48.0	51.0
75.	68.0	70.0	72.0	59.0	66.0	70.0	58.0	47.0	54.0	48.0	48.0	50.0
90.	70.0	71.0	73.0	70.0	69.0	71.0	72.0	57.0	67.0	59.0	60.0	64.0
105.	82.0	75.0	79.0	80.0	82.0	78.0	78.0	63.0	64.0	63.0	67.0	64.0
120.	67.0	77.0	78.0	73.0	69.0	69.0	63.0	49.0	57.0	46.0	53.0	51.0
135.	63.0	74.0	77.0	57.0	66.0	65.0	56.0	42.0	55.0	40.0	48.0	48.0
150.	62.0	71.0	72.0	55.0	62.0	61.0	64.0	45.0	50.0	39.0	45.0	47.0
165.	59.0	71.0	71.0	54.0	61.0	61.0	51.0	45.0	48.0	38.0	44.0	45.0
180	59.0	71.0	68.0	51.0	60.0	60.0	50.0	43.0	47.0	37.0	44.0	44.0
195.	58.0	69.0	60.0	52.0	60.0	58.0	50.0	42.0	46.0	37.0	44.0	43.0
225	58.0	68.0	59.0	48.0	57.0	58.0	48.0	40.0	44.0	37.0	40.0	41.0
255,	59.0	67.0	58.0	48.0	57.0	57.0	48.0	38.0	45.0	37.0	37.0	40.0

Expt. Ref. FIRE ON; HOPPER OPEN; FAN ON.

DAY 1.

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B	D B	W B	D B	W B	D B	W B	D B	W B	D B	W B	D B
0	53.0	56.8	49.7	57.3	47.9	56.1	51.3	59.9	51.6	59.5	49.1	50.5
15	53.0	57.3	49.1	57.3	47.2	56.1	49.5	59.7	51.1	58.6	48.8	56.5
30	63.0	68.0	49.5	58.2	48.1	57.8	51.8	60.6	51.1	60.4	49.3	58.2
45	56.3	61.3	52.5	61.1	50.7	61.1	53.3	62.7	52.3	62.0	51.3	59.7
60	56.1	62.0	53.3	62.5	51.8	62.3	53.9	64.3	53.0	62.9	51.8	60.6
75	57.5	64.3	54.5	63.9	53.0	63.5	55.6	65.2	54.3	64.7	53.3	61.6.
90	63.2	67.0	59.9	66.3	55.7	65.4	61.6	67.4	60.8	67.0	57.5	62.3
105	66.3	69.8	63.2	68.1	58.6	66.5	64.7	70.0	63.7	68.7	57.8	62.5
120	61.1	65.2	57.5	66.1	55.5	65.4	56.5	67.0	57.0	66.1	54.1	63.2
135	58.4	63.5	55.5	64.5	63.7	68.9	55.5	67.2	55.9	65.9	53.9	62.5
150	57.5	63.5	54.7	64.9	53.3	64.3	54.7	67.4	55.7	66.1	53.5	62.5
165	58.0	63.7	54.7	64.7	52.5	63.7	55.3	67.4	55.7	66.7	53.5	62.3
180	57.8	64.3	54.5	64.7	51.8	63.5	56.3	68.1	55.5	66.1	53.5	62.5
195	58.0	64.5	54.7	64.7	51.8	63.5	55.0	67.8	55.3	66.1	53.5	62.3
225	58.6	64.7	55.3	65.4	52.1	63.9	55.9	69.2	55.9	67.0	53.9	62.9
255	58.6	65.7	58.0	66.1	52.1	64.3	56.1	69.6	57.5	68.3	55.5	63.2

Expt. Ref. F.f.h.

DAY 2.

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W B	D B	W B	D B	W B	D B	W B	D B	W B	D B	W B	D B
0	56.3	63.2	53.9	62.3	51.6	59.7	54.7	65.7	56.3	65.7	53.0	62.0
15	57.0	63.9	54.5	62.7	52.1	60.2	54.7	66.1	56.1	65.7	53.3	62.0
30	57.8	64.7	55.3	63.9	53.0	62.5	56.1	67.8	57.3	61.0	53.9	62.3
45	60.4	68.7	58.2	67.4	56.7	64.7	58.0	69.0	58.4	68.9	55.7	63.7
60	62.0	71.0	59.5	69.4	57.0	67.2	58.0	71.5	59.2	71.5	56.1	64.7
75	62.5	72.3	61.1	71.3	59.0	69.8	59.7	72.9	60.2	72.9	57.0	66.5
90	69.6	77.5	65.7	74.6	62.7	71.0	66.3	76.3	66.5	76.3	61.8	68.7
105	71.9	78.1	69.2	76.3	65.7	73.2	67.6	77.7	68.1	77.5	63.5	69.6
120	65.2	73.9	63.5	74.3	61.6	72.1	62.3	76.8	63.5	76.1	59.2	69.8
135	63.7	73.9.	62.5	73.9	60.2	71.9	61.8	77.5	62.7	76.8	58.8	70.6
150	63.5	74.1	62.0	73.9	59.2	71.7	61.6	77.7	62.5	76.8	58.8	71.3
165	63.9	74.6	62.9	74.3	59.2	71.9	61.8	78.1	62.7	77.0	59.0	71.9
180	63.7	75.1	62.5	74.3	58.8	71.9	62.0	78.4	62.9	77.7	59.0	71.3
195	64.3	75.5	62.7	75.1	58.8	72.3	62.3	78.4	62.5	78.1	59.2	72.9
225	64.7	76.1	64.1	75.9	58.4	72.9	64.9	79.8	63.4	78.9	60.0	73.1
255	66.1	77.2	62.4	76.3	58.8	73.1	66.7	80.6	64.7	79.5	58.8	73.0

Expt. Ref. Fth.

DAY 3.

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	51·3	54·7	50·0	55·7	48·4	53·0	51·1	58·0	50·3	55·9	49·5	54·7
15	61·1	54·7	49·7	55·3	48·4	53·0	51·8	58·8	51·3	58·2	50·5	55·7
30	51·8	55·7	50·5	55·9	49·7	55·3	52·5	59·2	52·5	58·6	51·6	56·5
45	54·3	58·4	53·0	58·2	52·3	57·8	53·7	59·9	53·9	59·7	53·3	58·2
60	55·7	60·2	54·3	59·9	53·7	59·2	55·0	62·3	55·3	61·6	54·3	59·2
75	57·3	61·6	55·9	61·6	54·5	60·2	56·1	63·2	55·7	62·0	55·0	60·2
90	62·7	65·4	60·2	64·1	57·8	61·6	62·3	65·7	61·3	64·9	57·3	60·4
105	65·9	67·6	63·5	66·5	59·7	62·9	64·7	67·6	63·7	66·5	58·4	60·6
120	59·2	63·2	58·0	63·5	56·5	62·0	58·6	65·7	58·0	64·5	56·1	61·3
135	58·0	63·5	57·5	64·1	55·7	62·0	58·6	66·3	58·0	65·7	55·9	61·1
150	58·0	63·9	57·0	63·9	55·3	62·0	58·0	66·3	57·5	65·4	56·1	61·3
165	57·5	63·7	56·3	63·5	54·5	61·8	58·2	67·4	58·0	66·8	55·9	61·8
180	59·7	64·3	58·4	65·2	57·0	62·5	57·8	68·1	58·8	67·8	56·1	61·8
195	58·0	64·3	56·5	64·9	54·7	62·5	58·4	69·2	59·2	68·7	56·3	62·5
225	57·8	64·3	56·1	65·4	54·1	62·0	58·4	68·3	58·8	67·8	56·3	62·7.
255	58·0	65·2	56·3	65·4	54·3	62·5	58·0	68·5	58·0	68·3	56·1	62·7

Expt. Ref. Ffh.

DAY 4.

POS.	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.	W. B.	D. B.
0	56.8	62.7	54.7	62.0	53.0	59.9	57.0	65.4	57.0	64.7	54.3	61.3
15	56.5	62.7	54.5	62.3	53.0	60.4	57.0	66.1	56.8	64.7	54.1	61.6
30	57.5	64.3	55.6	63.5	53.9	61.6	58.0	67.8	57.5	67.4	54.5	62.5
45	60.4	68.3	58.4	67.0	56.3	64.9	59.5	70.3	58.8	69.4	56.3	64.3
60	61.8	69.8	59.5	68.5	57.8	66.5	60.4	71.5	59.7	70.8	57.0	65.4
75	63.7	71.7	60.8	70.6	58.8	68.3	62.0	72.3	61.1	71.7	58.4	66.1
90	69.6	75.6	66.8	73.2	63.5	69.8	68.5	76.5	67.0	74.3	62.7	67.4
105	71.0	76.3	67.2	73.9	64.7	70.8	68.1	75.1	67.4	74.6	63.9	68.5
120	63.7	71.0	62.0	72.1	60.6	69.6	63.5	73.9	62.5	72.7	59.9	67.6
135	62.7	70.8	61.1	71.7	59.0	68.7	62.5	74.1	61.6	72.9	58.8	67.8
150	62.5	71.0	60.6	71.0	59.0	68.7	62.9	74.6	62.5	72.9	59.2	67.8
165	62.3	71.0	60.4	71.5	58.4	68.7	63.2	74.6	62.7	73.4	58.8	68.1
180	62.9	71.9	60.2	72.1	58.4	69.2	62.9	75.9	62.0	74.8	58.6	68.5
195	62.6	71.9	60.2	71.9	58.4	69.2	63.2	76.9	62.7	75.1	59.2	70.0
225	62.5	71.7	60.8	72.3	58.2	69.4	63.2	76.5	62.3	74.6	59.2	70.8
255	62.7	72.5	61.1	72.3	59.5	69.8	63.7	77.0	62.5	75.1	60.2	71.3

RELATIVE HUMIDITY.

Expr. Ref. FIRE ON; HOPPER OPEN; FAN ON.

DAY 1

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	78.0	49.0	54.0	57.0	59.0	60.0
15	76.0	49.0	61.0	49.0	60.0	59.0
30	72.0	54.0	50.0	54.0	53.0	53.0
45	69.0	56.0	48.0	53.0	52.0	57.0
60	70.0	55.0	49.0	50.0	52.0	55.0
75	67.0	55.0	50.0	54.0	47.0	68.0
90	82.0	69.0	65.0	73.0	71.0	75.0
105	84.0	77.0	63.0	77.0	73.0	75.0
120	80.0	59.0	54.0	52.0	57.0	57.0
135	74.0	57.0	51.0	47.0	53.0	58.0
150	70.0	52.0	48.0	43.0	51.0	67.0
165	71.0	52.0	47.0	47.0	53.0	57.0
180	69.0	51.0	44.0	43.0	61.0	56.0
195	69.0	52.0	44.0	43.0	50.0	57.0
225	70.0	53.0	45.0	42.0	49.0	56.0
255	67.0	52.0	43.0	42.0	51.0	61.0

DAY 2

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	67.0	58.0	58.0	49.0	57.0	56.0
15	67.0	59.0	59.0	48.0	56.0	58.0
30	67.0	59.0	53.0	48.0	56.0	58.0
45	62.0	58.0	57.0	49.0	53.0	60.0
60	60.0	57.0	53.0	47.0	48.0	59.0
75	59.0	57.0	62.0	46.0	48.0	57.0
90	69.0	62.0	64.0	60.0	61.0	69.0
105	74.0	71.0	68.0	60.0	62.0	72.0
120	63.0	56.0	56.0	45.0	50.0	53.0
135	58.0	53.0	50.0	41.0	47.0	49.0
150	57.0	52.0	48.0	40.0	46.0	48.0
165	56.0	53.0	47.0	39.0	45.0	47.0
180	53.0	51.0	46.0	39.0	44.0	48.0
195	56.0	60.0	44.0	39.0	41.0	44.0
225	56.0	50.0	44.0	45.0	42.0	44.0
255	51.0	45.0	42.0	49.0	45.0	42.0

DAY 3

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	80.0	68.0	72.0	63.0	70.0	70.0
15	80.0	68.0	72.0	62.0	63.0	71.0
30	78.0	70.0	69.0	65.0	67.0	72.0
45	78.0	71.0	70.0	68.0	69.0	73.0
60	77.0	70.0	70.0	63.0	68.0	73.0
75	78.0	70.0	70.0	66.0	68.0	72.0
90	87.0	80.0	80.0	83.0	82.0	83.0
105	91.0	85.0	83.0	86.0	87.0	88.0
120	79.0	72.0	71.0	67.0	68.0	73.0
135	72.0	68.0	68.0	64.0	64.0	72.0
150	71.0	67.0	67.0	61.0	62.0	73.0
165	69.0	65.0	62.0	58.0	59.0	70.0
180	69.0	62.0	61.0	53.0	59.0	71.0
195	69.0	60.0	61.0	52.0	57.0	69.0
225	68.0	57.0	60.0	55.0	59.0	68.0
255	66.0	57.0	60.0	53.0	53.0	68.0

DAY 4

TIME	I_1	I_2	I_3	II_1	II_2	II_3
0	70.0	63.0	64.0	60.0	62.0	64.0
15	69.0	61.0	62.0	58.0	61.0	62.0
30	67.0	60.0	60.0	56.0	66.0	60.0
45	64.0	60.0	60.0	62.0	53.0	61.0
60	65.0	59.0	60.0	53.0	51.0	60.0
75	66.0	58.0	58.0	57.0	56.0	68.0
90	75.0	72.0	71.0	70.0	69.0	79.0
105	78.0	72.0	72.0	69.0	70.0	79.0
120	69.0	58.0	60.0	58.0	58.0	63.0
135	65.0	55.0	57.0	52.0	53.0	59.0
150	63.0	65.0	57.0	52.0	57.0	60.0
165	62.0	53.0	64.0	53.0	56.0	68.0
180	61.0	50.0	52.0	49.0	49.0	56.0
195	60.0	50.0	52.0	50.0	50.0	63.0
225	60.0	52.0	51.0	48.0	50.0	50.0
255	59.0	53.0	55.0	48.0	49.0	52.0

Protocols of the Pilot User-Test Experiments carried out in order to develop routine techniques for the assessment of physiological and subjective reactions of working subjects.

PILOT USER TEST STUDIES. Physical check on the Effect of a 6" x 6" extractor fan (air delivery 115 cu.ft. per minute).

PILOT-USER TEST EXPERIMENTS:
I PHYSICAL CHECK.
(WET BULB & DRY BULB TEMPERATURES)

(a) ALL WINDOWS & HOPPERS CLOSED.
6"x6" FAN EXTRACTING APPROX. 115 cu.ft/min.

POS	I_1		I_2		I_3		II_1		II_2		II_3	
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	58.0	63.9	56.3	63.5	56.1	61.8	56.3	64.3	57.0	63.5	57.3	62.3
15	58.8	64.7	57.0	64.1	56.1	62.3	56.8	64.5	57.3	63.9	57.3	62.0
30	59.2	65.4	58.0	64.7	56.3	62.7	58.6	66.3	58.8	64.9	57.5	62.5
45	64.9	71.0	62.5	68.7	58.6	64.7	63.5	70.6	62.9	68.3	59.2	63.7
60	67.4	73.2	64.7	70.8	60.2	65.7	65.2	72.3	64.9	70.0	60.6	64.3
75	69.6	75.9	67.0	72.5	60.6	66.1	68.1	73.9	67.4	71.9	60.6	64.7
90	76.8	80.2	73.9	76.3	63.2	68.1	70.1	79.5	75.1	76.3	61.8	65.7
105	81.0	83.3	77.7	79.1	63.7	68.3	81.2	82.0	78.1	78.9	62.9	66.3
120	75.1	78.0	72.9	75.3	61.3	67.6	72.7	75.3	72.1	73.9	61.8	66.3
135	71.7	75.1	70.0	73.2	61.3	67.4	69.6	73.2	69.6	72.1	62.0	66.5
150	69.8	73.7	68.3	72.3	62.0	67.2	68.3	72.3	68.3	71.3	62.0	66.3
165	69.2	72.9	67.0	71.7	63.5	67.4	67.6	71.9	67.6	71.0	61.1	66.5
180	68.7	72.7	67.2	71.5	61.8	67.2	67.0	71.7	67.0	70.8	61.8	66.5
195	67.8	72.3	67.0	71.3	60.2	66.5	66.1	71.3	66.5	70.3	61.1	66.1
225	66.3	70.6	64.7	69.8	59.9	66.1	66.4	70.3	65.2	69.2	60.2	65.7
255	66.5	70.0	64.3	70.0	59.7	66.1	64.5	70.0	64.7	68.9	60.6	65.9

(b) RIGHT HAND HOPPER OPEN
6"x6" FAN EXTRACTING APPROX. 115 cu.ft/min.

POS												
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	57.5	65.2	57.5	64.7	58.0	62.0	58.4	65.9	59.2	[illegible]	57.5	[illegible]
15	60.2	65.9	58.0	64.7	57.5	62.5	58.8	64.1	58.4	60.7	57.5	61.8
30	60.8	66.1	56.5	65.2	58.0	65.7	59.7	66.8	57.7	65.2	[illegible]	62.7
45	65.2	70.0	62.5	67.2	57.7	64.7	65.9	70.0	65.5	68.3	57.7	65.7
60	68.3	73.7	65.9	72.1	61.8	66.8	66.5	72.3	66.0	70.0	61.3	64.9
75	70.6	76.1	67.8	73.7	64.1	67.4	68.9	74.3	68.5	72.1	62.7	65.4
90	77.8	80.6	75.9	77.7	65.2	70.0	79.4	79.9	76.5	77.7	65.4	66.3
105	79.5	80.0	75.9	78.4	66.3	70.0	80.6	81.3	77.8	77.8	65.9	66.8
120	74.1	76.8	72.1	75.7	67.0	69.6	71.7	74.8	71.7	74.1	65.2	67.2
135	70.8	74.1	68.5	73.2	64.3	68.1	70.0	73.9	70.8	73.2	66.7	67.4
150	69.8	74.6	67.8	73.9	65.2	68.5	68.5	73.2	69.2	72.3	64.9	66.4
165	64.5	68.7	62.3	68.1	59.9	64.2	60.8	65.7	60.8	65.4	58.6	60.8
180	62.8	67.5	61.0	67.5	60.1	62.8	61.5	67.2	62.2	65.3	58.7	61.5
196	64.7	69.4	62.6	67.8	59.5	63.7	61.8	67.4	62.6	66.3	59.7	62.3
225	66.8	73.4	65.4	72.9	64.3	68.3	65.2	71.5	65.4	70.3	[illegible]	66.3
255	66.8	73.7	64.3	72.4	63.7	68.5	64.3	72.1	64.9	70.8	62.7	66.8

(c) CASEMENT WINDOWS AND DOOR OPENED.
VENTILATION ROUTINE AS FOR SUBJECT A
DAY I.

POS												
TIME	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	61.6	65.9	62.5	66.5	61.6	65.9	62.0	66.8	61.8	66.8	61.3	66.3
15	60.8	66.1	61.8	66.3	60.6	65.9	61.1	66.5	60.8	66.5	60.6	66.1
30	61.3	67.0	62.0	67.0	61.1	66.5	62.0	67.8	61.6	67.8	61.1	67.2
45	63.2	70.8	62.9	68.9	61.8	68.3	62.5	69.6	61.6	69.4	61.1	68.5
60	64.3	72.3	63.7	70.6	61.8	69.6	61.8	70.0	61.6	69.8	60.8	68.9
75	64.5	73.2	64.1	71.7	62.0	70.6	63.5	71.0	62.6	71.3	61.6	69.6
90	70.6	76.1	67.0	73.2	64.9	71.5	68.9	72.7	66.1	72.5	64.3	70.6
105	73.9	78.4	68.3	74.1	65.4	71.5	69.8	74.8	67.0	73.2	64.7	70.6
120	64.7	72.5	64.7	71.7	62.3	70.6	62.9	71.0	62.3	71.0	62.0	70.3
135	64.3	72.5	64.5	71.7	62.5	70.6	62.0	70.6	61.6	70.6	61.6	69.6
150	63.2	71.9	63.9	71.5	62.0	70.6	61.8	70.3	61.6	70.3	61.1	69.8
165	62.9	71.7	63.9	71.3	61.8	70.3	61.8	70.0	61.8	70.3	61.1	69.8
180	63.2	70.8	63.9	71.0	61.8	69.8	61.8	69.8	61.6	70.0	61.3	69.4
195	63.7	71.5	65.2	71.0	62.5	70.0	62.3	70.0	62.5	70.3	62.0	69.8
225	63.2	71.3	64.3	70.8	61.8	69.6	62.5	70.6	62.5	70.6	62.0	69.6
255	63.2	71.5	64.1	70.8	62.0	70.0	62.0	70.8	62.0	71.0	61.8	70.3

PILOT USER TEST STUDIES. Subject A washing.
Ventilation arranged by working subject.

PILOT USER - TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA:-

SUBJECT A. DAY 1. (Ventilation arranged by Subject)

TIME (MINS)	PHYSIOLOGICAL DATA: CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁶	FOREHEAD SKIN TEMP. °F	ORAL TEMP. °F	SENSATIONS OF HEAT + MOISTURE	PHYSICAL DATA: W.B. & D.B. TEMPERATURES (°F) I_2 W.B.	I_2 D.B.	II_1 W.B.	II_1 D.B.	II_2 W.B.	II_2 D.B.	II_3 W.B.	II_3 D.B.
0	82.5	9.1	93.5	98.4		57.0	64.1	58.0	64.9	57.0	64.7	56.8	65.5
15					0	57.3	64.5	57.3	64.1	57.5	64.1	56.5	65.7
30						59.0	65.7	58.4	66.1	57.5	64.5	57.5	65.5
45						60.2	61.6	60.6	68.3	60.6	61.4	60.2	64.7
60	65	8.5	96.8	98.8		60.6	68.7	61.1	67.2	61.1	69.1	59.0	65.2
75					+2	62.7	61.8	62.7	69.2	65.5	69.4	60.2	65.7
90						60.2	69.7	61.8	69.7	65.7	64.3	61.5	66.1
105						61.3	69.2	62.0	69.8	61.3	64.1	60.4	61.0
120	82.5	13.6	94.3	98.8		54.9	68.7	62.9	69.8	65.9	69.4	61.6	66.5
135					0	57.2	61.4	57.2	61.8	57.2	61.2	63.2	65.7
150						58.0	66.5	58.6	61.2	57.2	67.2	58.4	65.7
165						58.6	66.8	58.2	61.0	57.0	67.2	58.4	65.9
180						57.2	61.4	58.8	61.4	[illegible]	61.4	58.6	65.1
185	72.5	75.9	95.7	99.0									
195					+1	60.4	68.5	59.0	68.5	57.1	68.5	54.7	61.0
225						57.0	68.1	58.2	69.1	57.0	68.1	58.4	66.5
236	82.5	77.8	96.0	99.0									
255					0.	57.9	68.7	57.2	68.1	57.0	68.3	58.4	66.5
275	82.5	70.0	95.5	99.0									

NOTES
(subjects procedure etc).

T-0 R.H. & L.H. casement windows closed. R.H. [illegible] windows also opened.
T-30 Gas heater switched on.
T=8 to T-56 Subject scrubbing at sink.
T-45 Door opened.
T-75 Gas turned low.
T-95. Gas full on.
T-120 Gas turned off.
T-125 to T=140. Subject took lunch.
T-180 commenced washing followed by hanging out clothes to dry in [illegible].
T-236 Subject finished working.

PILOT USER TEST STUDIES. Subject A washing.
Ventilation by Right Hopper Window only.

PILOT USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA:-

SUBJECT A. DAY 2. (Right hopper only open)

TIME (MINS)	PHYSIOLOGICAL DATA:- CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁶	FOREHEAD SKIN TEMP. °F	ORAL TEMP. °F	SENSATIONS OF HEAT + MOISTURE	PHYSICAL DATA:- W.B. & D.B. TEMPERATURES (°F) I W.B.	I D.B.	II₁ W.B.	II₁ D.B.	II₂ W.B.	II₂ D.B.	II₃ W.B.	II₃ D.B.
0	92.5	16.4	92.0	98.0									
15						56.5	62.0	57.3	62.9	56.5	62.0	55.4	61.1
30					+3	56.8	62.3	57.0	62.4	56.5	61.8	56.0	61.3
45						58.2	63.7	57.5	63.7	57.0	62.7	55.4	61.6
60	67.5	51.0	94.6	98.4		61.6	61.0	62.5	66.8	61.1	65.9	58.2	63.2
75						62.7	68.1	63.5	61.8	62.5	61.4	54.2	63.9
90					+2	66.3	69.4	68.3	70.6	65.2	69.4	60.6	64.1
105						68.3	70.8	68.3	70.6	66.1	68.5	61.6	64.7
120	57.5	95.0	96.0	99.0		69.4	71.9	71.0	73.4	68.7	70.6	63.7	66.1
135					+5	65.7	68.7	61.2	64.6	67.0	68.5	63.7	66.1
150						63.2	61.6	63.9	67.4	63.4	61.4	61.6	65.7
165						62.0	66.3	62.9	66.8	62.9	66.5	61.8	65.4
180						60.8	65.7	61.6	65.9	61.6	65.7	60.8	64.5
185	45	66.0	95.5	99.0		60.6	65.7	61.1	65.4	60.6	65.2	60.4	64.3
195					+1	.							
225						60.4	65.2	61.1	65.7	60.4	65.2	57.4	64.3
236	82.5	57.0	94.8	98.6		59.2	64.5	57.4	64.5	57.4	64.3	57.0	63.7
255					0	.							
275	77.5	67.0	95.4	98.2		57.7	64.3	60.2	64.3	57.0	64.1	57.0	62.9

NOTES.
(Subject's procedure etc.)

From T=10 to T=55 Subject washing at sink.
T=30 Gas boiler switched on.

T=75 Gas turned down

T=105 Gas turned off.
T=125 to T=138 Subject took lunch.

T=180. Subject commenced wringing and hanging out clothes to dry in corridor.

T=236 Subject finished working.

PILOT USER TEST STUDIES. Subject B washing.
Ventilation arranged by working subject.

PILOT USER-TEST EXPERIMENTS.
PHYSICAL & PHYSIOLOGICAL DATA.

SUBJECT B. DAY 5. (Ventilation arranged by subject)

	PHYSIOLOGICAL DATA:-					PHYSICAL DATA:- W.B. & D.B. TEMPERATURES (°F)							
						I_2		I_1		II_2		II_1	
TIME (MINS)	CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS^{-1} x10^{-6}	FOREHEAD SKIN TEMP. °F	ORAL TEMP °F	SENSATIONS OF HEAT + MOISTURE	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.
0	82.5	4.0	93.1	97.3		51.0	61.1	51.8	62.5	51.5	62.0	56.3	60.8
15					-1	51.5	62.7	51.5	62.5	51.5	62.0	56.8	60.8
30						57.1	64.1	57.1	64.3	58.0	63.2	57.3	61.6
45						61.8	61.0	62.7	61.4	62.0	66.1	57.1	62.7
60						61.1	66.5	63.7	61.8	63.2	61.0	57.7	63.2
75	52.5	61.1	91.3	98.6	+2	62.0	68.3	64.3	69.2	64.1	61.8	60.6	63.7
90						65.7	70.6	61.0	70.0	65.2	68.4	60.6	64.1
105						64.5	70.3	61.0	70.3	61.2	67.4	62.0	65.2
120	80	74.9	90.6	97.8		62.7	69.2	64.5	68.1	63.7	68.3	62.0	65.2
135					+3	60.4	61.6	62.0	66.8	62.0	61.0	61.3	65.2
150						54.9	67.4	60.2	66.1	60.8	66.1	60.4	64.5
165						60.4	61.6	60.4	66.3	60.6	66.1	60.4	64.3
180						60.4	66.8	60.8	66.3	60.2	65.1	57.1	64.3
185	80	20.1	92.4	97.2									
195					0	61.1	67.8	61.6	66.3	61.1	66.5	60.4	64.5
225						58.8	65.7	59.2	65.4	57.1	65.7	57.7	64.1
245	67.5	25.5	90.5	97.2									
255					0	59.4	66.1	58.8	65.1	57.0	65.4	57.2	64.3
280	12.5	14.6	94.8	98.2									

NOTES
(subjects' [illegible])

T=0 Right window fully opened.
T=30 Gas heater switched on.
T=40 to T=75 subject scrubbing at sink.
T=40. Right casement windows opened, T=40 left [illegible] opened.
T=75 Gas turned down.
T=105 Left window opened.
T=110 Gas turned off.
T=120 to T=135 subject took [illegible].
T=140 Commenced wringing and hanging out clothes to dry in [illegible].
T=245. subject finished working.

PILOT USER TEST STUDIES. Subject B washing. Ventilation by Right Hopper Window only.

PILOT USER-TEST EXPERIMENTS.
PHYSICAL & PHYSIOLOGICAL DATA

SUBJECT B. DAY 4 (Right hopper only open)

TIME (MINS)	PHYSIOLOGICAL DATA:- KAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹ x10⁻⁶	FOREHEAD SKIN TEMP. °F	ORAL TEMP. °F	SENSATIONS OF HEAT + MOISTURE	PHYSICAL DATA:- W.B. & D.B. TEMPERATURES (°F) I₁ W.B.	I₁ D.B.	II₁ W.B.	II₁ D.B.	II₂ W.B.	II₂ D.B.	II₃ W.B.	II₃ D.B.
0	85	0.9	94.2	98.0		60.2	65.2	60.2	65.9	60.2	65.7	58.6	63.7
15					+1	61.1	66.5	61.3	66.5	60.8	66.1	58.8	63.7
30						62.0	67.2	62.1	67.6	63.5	68.1	61.1	65.2
45						66.5	71.9	67.2	71.7	66.1	70.3	62.7	66.1
60						68.1	73.1	68.9	73.4	68.5	72.7	64.1	67.2
75	55		93.8	98.0	+9	71.0	75.1	72.1	75.5	71.3	74.8	65.4	67.6
90						73.2	77.3	75.1	76.8	73.1	75.5	66.5	68.3
105						76.8	79.1	71.8	78.9	75.5	76.8	66.5	68.7
120	27.5		92.8	98.8		71.5	76.3	72.5	75.5	72.9	75.1	67.4	68.9
135					+3	69.8	75.1	70.6	74.1	71.3	74.8	67.0	68.9
150						67.8	73.7	68.7	72.5	69.2	72.5	66.3	69.2
165						67.4	73.2	68.1	72.1	67.8	71.9	65.9	68.7
180						67.4	73.4	67.4	72.3	67.4	71.9	65.9	68.9
185	50	128.7	91.8	98.8									
195					+2	67.6	73.7	68.1	72.5	68.1	72.7	64.9	68.9
225						66.3	72.5	67.4	72.3	67.8	72.1	65.9	68.9
245	70	93.3	93.1	98.4									
255					+2	65.7	72.7	67.4	72.5	67.4	72.3	64[illegible]	68.7
280.	72.5	31.1	94.3	98.2									

NOTES
(subject's [illegible] [illegible])

T=30 Gas boiler switched on.
T=40 to T=75 subject scrubbing at sink.
T=70 Gas turned down.
T=105 Gas full on
T=110 Gas turned off.
T=120 subject took [illegible] till T=135
T=160 subject commenced wringing and [illegible] out clothes in drier.
T=245: subject finished working.

Protocols of the Full-Scale User-Test Experiments carried out on Working and Control Subjects.

FULL-SCALE USER-TEST STUDIES.

Day 1. Subject B washing; Subject A control. Ventilation arranged by Subject B.

FULL-SCALE USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA.

DAY 1. WORKING SUBJECT:- B; CONTROL SUBJECT:- A } VENTILATION ARRANGED BY SUBJECT B

TIME (MINS)	Subject B: Crampton Index	Subject B: Forehead Skin Conductivity $ohms^{-1} \times 10^{6}$	Subject B: Summated Sensations of Heat + Moisture	Subject A: Crampton Index	Subject A: Forehead Skin Conductivity $ohms^{-1} \times 10^{6}$	Subject A: Summated Sensations of Heat + Moisture	I_4 W.B.	I_4 D.B.	II_1 W.B.	II_1 D.B.	II_2 W.B.	II_2 D.B.	II_3 W.B.	II_3 D.B.		NOTES ([illegible])
0	95	0.8		85	3.4											
4					3.4											
8		1.6														
10					1.3											
11			-1													
12						-3										
15		1.3														
20				85	2.4											
22																
23		1.1	0			-2										EXTERNAL:- W.B. 49.0°F D.B. 53.0°F; CORRIDOR:- W.B. 54.0°F D.B. 56.0°F
27																
30	100				0.3		56.0	59.6	54.4	59.8	53.8	59.3	54.0	59.1	SORTING	T=30 LEFT & RIGHT CASEMENT WINDOWS SLIGHTLY OPENED
34		0.3														
40				85	2.1											
45					1.1		57.4	60.7	55.6	61.2	55.4	60.9	55.1	59.8		
47						-2										
48		2.3	+1													
53					4.8											
56		0.3	+3			-2										
60	90						58.5	63.8	56.4	62.1	56.0	61.7	55.8	60.5		T=60 GAS WASH BOILER LIT
62					0.7										WASHING	
63				90												
67		2.2	+3		2.5										INCLUDING	
71						-1										
75							61.2	65.5	61.2	66.2	60.7	65.3	57.6	61.2	SCRUBBING	
80				85	2.2											
82		0.1													AT	
87					2.2											
88	75	0.6													SINK	
90							63.4	67.9	63.6	68.4	62.8	67.1	59.3	62.6		
97		0.1														
100				90	1.4											T=100 RIGHT HOPPER FULLY OPENED.
105		0.6					64.0	68.4	63.8	68.2	62.6	67.3	59.8	63.0		
110					1.8											
112			+3			+1										
117					3.9											
119		1.0														
120	85						66.9	69.7	67.2	71.4	66.2	70.1	61.2	63.6		
124			+5	75		+2										T=125 BOTH CASEMENT WINDOWS HALF OPENED
127					1.8											
128		1.4														
135							65.3	67.5	61.7	70.4	65.5	67.3	61.4	64.0	WRINGING	
137		0.6														
138																
139					3.2											
140				90												
141			+4			+1										
150	65	0.6			0.7		63.0	63.8	68.2	70.4	64.8	65.8	58.9	62.8		T=150 GAS WAS TURNED OFF
155					0.6											
156		2.2													SCRUBBING	
158					0.6										AND	
160				90											RINSING	
165		2.1					62.6	65.3	62.8	66.0	63.0	65.5	59.1	63.3	AT	
167					2.2										SINK.	
180	65	1.0					61.4	64.4	59.8	64.4	59.8	64.2	59.1	62.8		
182					1.5											
185				80		-2										
195							60.9	64.4	59.3	64.2	58.5	63.6	58.5	62.4	BOTH SUBJECTS TOOK LUNCH IN AN ADJOINING ROOM.	
199					1.4											
200				90												
205					0.4											
208		1.1														
210	105						60.7	64.0	59.3	64.4	59.3	64.6	58.5	62.6		
216					0.5										RINSING	T=215 RIGHT CASEMENT WINDOW CLOSED.
220		3.4		90											AND	
222						0									WRINGING.	
225							62.8	66.0	59.8	65.3	59.8	65.0	59.6	63.3		
227					0.7											
230		1.4														
240	60	0.6	0		0.5	-1	62.6	65.8	61.4	65.8	61.2	65.4	59.8	63.3		EXTERNAL W.B. 52°F D.B. 56°F; CORRIDOR W.B. 53°F D.B. 58°F
245				85												
250					0.4										HANGING OUT CLOTHES.	
260		0.6		85												
270	70	0.7			0.7		61.8	65.0	60.0	65.0	59.8	64.6	60.3	63.6		
280				85	0.2											
290					0.1										SUBJECT B	
300	95						60.9	65.0	59.3	64.6	59.1	64.2	59.1	63.6	RESTING.	
305				90												
310			0			0										
315						-2										
320				90												
325					0.3											
326			-2			-2										
330	95						60.7	64.4	59.3	64.8	59.1	64.6	59.3	63.6		

FULL-SCALE USER-TEST STUDIES.
Day 2. Subject A washing; Subject B control
Ventilation arranged by Subject A.

FULL-SCALE USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA

DAY 2 — WORKING SUBJECT A; CONTROL SUBJECT B — VENTILATION ARRANGED BY SUBJECT A

TIME (MINS)	PHYSIOLOGICAL DATA:- SUBJECT A: CRAMPTON INDEX	SUBJECT A: FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹ × 10⁶	SUBJECT A: SUMMATED SENSATIONS OF HEAT + MOISTURE	SUBJECT B: CRAMPTON INDEX	SUBJECT B: FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹ × 10⁶	SUBJECT B: SUMMATED SENSATIONS OF HEAT + MOISTURE	PHYSICAL DATA:- W.B & D.B TEMPERATURES (°F) I_2 W.B	I_2 D.B	II_1 W.B	II_1 D.B	II_2 W.B	II_2 D.B	II_3 W.B	II_3 D.B	NOTES
0	85	0.28	-2	100	1.0										
5					1.0	+2									
8		1.10													
11			0		3.9	+2									
17		0.6			2.1										
20		0.5	-2	100											
21					1.0	+2									
30	85		0				59.1	62.4	58.1	62.4	58.1	62.1	57.1	60.5	SORTING
35					2.2										
36		0.1	0												
38						+1									
40				85											
45							60.7	63.6	59.8	63.6	59.6	63.3	57.1	60.9	
47		2.2	+2												
49						-1									
55					1.0	-1									
57		1.1	+1												
60	85						60.9	64.6	59.8	63.8	59.8	63.6	58.1	6	
65				90											
71		1.3			1.4										
73			+2			0									WASHING INCLUDING SCRUBBING AT SINK.
75							64.6	68.6	64.8	68.2	60.4	67.3	59.6	62.8	
80		1.8	+2	95											
82					2.1	0									
90	75	1.0					66.4	69.1	66.4	69.1	65.8	67.0	61.2	62.8	
100				90	2.0										
102		0.8													
103			+3												
105							66.5	68.2	66.2	69.1	65.3	67.9	60.1	64.2	
109					1.1	0									
113		1.1													
114			+3			+1									
120	75		+3				65.8	68.4	68.2	70.1	61.3	68.2	62.6	64.6	
125				85	0.1	+1									
126		1.1	+2												
132		1.5													
134					0.7										
135			+2			+2	68.8	70.1	66.6	69.5	65.8	68.4	62.6	65.3	
140				95											
144		1.4	+2			+4									
150	80	1.7					64.8	68.4	67.5	69.3	65.5	68.4	62.6	65.3	
154			+2			+2									
160				100											
164		1.3	+2												
165						+1	63.8	66.2	64.0	67.7	63.6	67.3	60.7	64.8	
170					0.7	+1									
171		0.3	+1												
180	80						65.0	66.2	64.2	66.2	63.0	66.0	61.2	64.8	
183					2.0	+2									
185		1.8	+2	85											
187															BOTH SUBJECTS TOOK LUNCH IN AN ADJOINING ROOM.
200				105			61.4	64.4	60.5	64.8	60.5	64.6	62.6	60.0	
210	95	0.1	0				60.5	64.0	59.6	64.6	59.8	64.6	58.7	63.6	
214					1.4										
220				105											
225					0.8		60.1	64.2	61.2	65.8	61.2	65.8	60.3	64.0	
226		1.1	0												WRINGING
232						+1									
240	90	1.0	0				60.7	64.2	60.9	65.5	60.7	65.3	59.3	64.0	
241					0.5										
245				105											
256					0.8	0									HANGING OUT CLOTHES.
260		0.6	-1	100											
270	75						59.3	63.6	58.9	64.0	58.9	64.4	58.5	63.6	
271					8.4	+1									
275		0.1	0												
278					1.1										
280				85											
300							60.3	64.4	60.0	64.8	59.6	64.6	58.1	63.3	SUBJECT A RESTING.
305				90											
306			-2		1.1	+1									
310		0.3													
315	85														
320				90	2.9										
330		0.3	-2				59.3	64.0	58.7	64.2	58.1	64.2	57.6	63.5	
337		0.4			0.7	-1									
340				75											
345	90														

NOTE: [illegible]

EXTERNAL: W.B 56.0°F D.B 56.0°F
CORRIDOR: W.B 56.0°F D.B 57.0°F

T=60 GAS WASH BOILER LIT

T=75 LEFT CASEMENT WINDOW HALF OPENED

T=92 RIGHT CASEMENT WINDOW HALF OPENED

T=105 RIGHT CASEMENT WINDOW FULLY OPENED

T=120 GAS TURNED DOWN

T=150 GAS TURNED OFF

T=185 LEFT CASEMENT WINDOW FULLY OPENED

EXTERNAL: W.B 56.0°F D.B 58.0°F
CORRIDOR: W.B 60.0°F D.B 60.0°F

FULL-SCALE USER-TEST STUDIES.

Day 3. Subject B washing; Subject C control. Ventilation by Right Hopper Window only.

FULL-SCALE USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA.

DAY:- 3 WORKING SUBJECT :- B
CONTROL SUBJECT :- C

} RIGHT HOPPER OPEN ONLY.

TIME	PHYSIOLOGICAL DATA						PHYSICAL DATA								NOTES. (Subjects procedure etc).
	SUBJECT B			SUBJECT C			W.B. & D.B. TEMPERATURES (°F)								
	CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹ 10⁶	SUMMATED SENSATIONS OF HEAT + MOISTURE	CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹ 10⁶	SUMMATED SENSATIONS OF HEAT + MOISTURE	I_2		II_1		II_2		II_3		
(MIN.)							W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	W.B.	D.B.	
0	45			80											
12		1.5	+1												
15					3.9	-1									
19		2.8	+1												
20				75											
22					2.2	-2									
25		2.1	+1												
30	85						58.1	60.7	51.1	61.4	51.4	61.2	56.2	54.8	SORTING. EXTERNAL W.B. 54.0°F D.B. 59.0°F; CORRIDOR W.B. 55.0°F D.B. 60.0°F
32					1.5	-1									
36		2.2	+1												
40				90											
42		1.9	+1												
45					1.0	-2	58.5	61.7	58.3	62.1	58.3	61.9	56.6	60.0	
47		1.5	+2												
51					1.5	-5									
60	50						60.9	65.3	60.3	64.0	60.0	64.0	58.5	61.9	WASHING. T=60 GAS WASH BOILER LIT.
64		3.6	+6		2.8	+2									
65				85											INCLUDING
74					2.8	+4									
75		9.4	+8				65.6	61.7	64.8	68.4	67.0	61.5	54.6	62.4	SCRUBBING
80		4.5	+7	80											
84					2.4	+6									AT
86		67.7	+9												
90	30						66.0	69.7	66.2	69.7	65.5	68.8	60.9	63.6	SINK.
92					3.8	+5									
94		12.0	+9			+2									
100				75											
103		10.4	+11												
105					2.6	+7	67.9	71.6	68.4	71.4	67.9	70.9	62.4	64.8	
114			+13												
118					5.6	+9									
120	30						64.3	72.4	70.4	73.8	69.7	72.6	64.0	66.2	
122		10.1	+13												
125				85											
132		13.2	+13												
133					2.1										WRINGING.
135							69.5	72.0	68.6	72.0	68.4	72.0	64.4	66.6	
137			+13												
140				85											
146		12.4													
149					2.4	+8									
150	35						68.8	71.4	68.8	71.6	68.8	71.4	64.8	66.6	T-150 GAS TURNED OFF.
156		22.8	+11												SCRUBBING
160				80											AND
165		34.4	+14		5.7	+6	69.1	71.8	68.8	71.1	68.6	71.1	64.8	66.6	RINSING
170		34.4	+14		3.6	+6									AT
174		41.6	+15												SINK.
180	50						68.2	70.1	66.6	69.4	67.1	70.1	64.8	67.1	
185				80											
190															BOTH SUBJECTS
200				75			67.3	69.5	65.3	68.4	65.3	68.4	64.0	67.1	TOOK LUNCH IN ADJOINING
210	65														ROOM.
212					2.8	+2	65.8	68.4	64.2	67.8	64.4	68.2	63.6	66.2	
215		4.7	+3												
220				85											
222		3.1	+3												RINSING
225					1.8	+1	66.2	69.3	64.8	68.6	64.8	68.8	63.6	66.2	AND
230		8.7	+3												WRINGING.
231					2.1	+4									
240	45						66.2	68.8	64.8	68.6	64.8	68.8	63.6	66.2	
241		4.1	+9		4.1	+2									EXTERNAL:- W.B. 57.0°F D.B. 63.0°F
245				85											CORRIDOR:- W.B. 58.0°F D.B. 63.0°F
252					2.8	+1									
255		4.5	+4												HANGING OUT CLOTHES.
260				95											
265		5.2	+7												
266					1.7	+1									
270	65						66.0	68.4	64.4	68.4	64.6	68.6	63.3	66.2	
272					1.7	+1									
274		4.8	+4												SUBJECT B
280				90											
283		5.0	+3												
285					1.7	+1									RESTING.
291		2.5	+4												
297					1.7	+1									
300	95	4.6	+3				65.0	67.9	64.0	68.2	64.0	68.2	63.0	66.0	
305				100											
311		2.1	+3												
313					1.5	0									
320				100											
324		2.4	+3												
327					1.3	0									
330	90						64.8	67.7	64.0	68.2	63.8	68.2	62.6	65.4	
335				85											

FULL-SCALE USER-TEST STUDIES.
Day 4. Subject A washing; Subject B control.
Ventilation by Right Hopper Window only.

FULL- SCALE USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA.

DAY:- 4 WORKING SUBJECT:- A; CONTROL SUBJECT:- B } RIGHT HOPPER OPEN ONLY.

TIME	PHYSIOLOGICAL DATA:- SUBJECT A: CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁶	SUMMATED SENSATION OF HEAT + MOISTURE	SUBJECT B: CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁶	SUMMATED SENSATION OF HEAT + MOISTURE	PHYSICAL DATA:- W.B. & D.B. TEMPERATURES (°F): I_2 W.B	I_2 D.B.	II_1 W.B.	II_1 D.B.	II_2 W.B.	II_2 D.B.	II_3 W.B.	II_3 D.B.	NOTES. subject's procedure etc.
MINS.															
0	90			105	0.6	+1									
5		1.2	0												
13		2.5	0												
20				105											
25		0.7	0												
30	95						57.4	61.7	56.2	61.2	56.2	60.9	55.6	59.3	
32					0.4	+1									SORTING. EXTERNAL:- W.B. 54.0°F D.B. 54.0°F
35		1.8	0												CORRIDOR:- W.B. 55.0°F D.B. 60.0°F
40				95											
45					1.1	+1	59.1	62.6	58.5	63.0	58.3	62.6	55.8	60.3	
46		4.2	+3												
53					2.2	+1									
54															
60	75				1.1	+1	60.5	64.4	58.7	63.6	58.9	63.6	57.6	61.4	T=60 GAS WASH BOILER LIT...
61		0.7	+3												
65				80											
67		3.5	+5		0.4	+2									
74					1.6	+2									
75							63.6	67.7	64.4	68.2	63.6	67.3	59.1	62.1	WASHING
76		3.2	+6												
80				85											
83					1.0	+3									INCLUDING
87		6.2	+6		2.1										SCRUBBING
89		10.7	+6												
90	10						65.3	70.0	67.1	72.0	66.6	70.1	60.7	63.6	AT
98					3.1	+4									
99		9.7	+8												SINK.
100				90											
104		13.7	+8												
105						+5	68.8	72.7	69.3	73.8	68.8	71.8	62.1	64.4	
111					1.4	+5									
115		17.2	+10												
120	40						71.8	74.0	74.1	76.0	72.8	75.5	63.3	66.0	T=120 GAS TURNED DOWN.
122		44.3	+11												
124					2.0	+6									
125				75											
128					3.5	+6									
130		34.3	+11												
135							73.8	75.8	77.4	77.8	75.6	76.4	64.0	66.6	
138					3.5	+6									
140		45.7	+11	85											
141		60.3	+11												
149					3.5	+6									
150	45						75.2	75.6	80.2	80.2	76.9	76.9	64.4	66.2	T-150 GAS TURNED OFF
160				80											
164					6.9	+3									
165		22.5	+6				70.7	72.6	71.6	73.2	71.4	72.4	64.4	66.6	
174					2.7	+2									
178		8.9	+3												
180	65						70.1	72.0	70.1	72.6	70.1	72.0	63.8	66.6	
182					1.4	+2									
185				85											
195							68.2	69.7	66.6	69.7	66.6	69.3	61.2	65.5	BOTH SUBJECTS
200				70											TOOK LUNCH IN
201					2.1	+1									ADJOINING ROOM.
210	100						67.1	69.5	66.0	69.5	66.2	69.3	63.0	66.2	
214		9.5	+3												
216					1.3	+3									
220		4.2	+3	80											
222					1.8	+3									WRINGING.
225							61.5	70.4	66.2	70.4	66.6	69.7	63.6	66.0	
226		6.0	+3												
232					4.5	+3									
234		3.9	+3												
240	65						68.6	70.7	67.9	70.9	67.7	70.1	63.8	66.4	EXTERNAL:- W.B. 57.0°F D.B. 60.0°F
245				70	2.1	+3									CORRIDOR:- W.B. 58.0°F D.B. 60.0°F
247		6.8	+3												
250		1.2	+3	80											
256		8.4	+3			+3									HANGING OUT CLOTHES.
267															
270	80						67.5	69.7	66.2	69.9	66.4	69.9	63.6	66.6	
271		2.1	+3												
274		2.5	+3												
277					1.5	+3									
278															
280		2.8	+3	85											SUBJECT A
287		1.1	+1												RESTING.
289					2.8	+3									
300	90				1.3	+2	66.4	69.3	65.3	69.7	65.8	69.3	62.6	66.–	
305		5.9	-1	80											
310				75											
330	85	1.3	-2				66.2	69.3	65.3	69.7	65.3	69.3	63.0	66.4	
333					0.8	+2									

FULL-SCALE USER-TEST STUDIES.

Day 5. Subject C washing; Subject E control. Ventilation arranged by Subject C.

FULL-SCALE USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA.

DAY:- 5 WORKING SUBJECT :- C / CONTROL SUBJECT :- E } VENTILATION ARRANGED BY SUBJECT C

	PHYSIOLOGICAL DATA:- SUBJECT C			SUBJECT E			PHYSICAL DATA:- W.B. & D.B. TEMPERATURES °F.								NOTES	
TIME	KAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS.10⁻⁶	SUMMATED SENSATIONS OF HEAT +MODERATE	KAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS.10⁻⁶	SUMMATED SENSATIONS OF HEAT +MODERATE	I_2 W.B.	I_2 D.B.	II_1 W.B.	II_1 D.B.	II_2 W.B.	II_2 D.B.	II_3 W.B.	II_3 D.B.		
(MINS).																
0	80	3.4	+2	100												
10					0.1	0										
15		3.1	+2													
20				70	0.4	0										EXTERNAL:- W.B. 57.0°F D.B. 60.0°F
25		7.3	+2													CORRIDOR:- W.B. 58.0°F D.B. 60.0°F
30	80				0.4	0	62.1	64.8	61.9	65.8	61.7	65.5	60.0	63.3		
32															SORTING	T-35. RIGHT CASEMENT WINDOW FULLY OPENED.
40		2.2	+2	75												
44					0.1	-2	61.9	64.6	61.2	65.3	60.4	65.3	59.8	63.8		
50		1.3	+3													
51					0.2	-2										
55		2.4	+2													
60	70	8.3	+5				63.6	66.9	61.4	66.0	61.7	66.2	60.7	64.4		T-60 GAS WASH BOILER LIT.
61					0.3	-2										
65		5.6	+3	95												
75		12.8	+8				64.0	67.5	64.4	68.3	64.0	68.2	61.9	65.0	WASHING	
76					0.1	0										
80		38.8	+8	75											INCLUDING	
85		36.4	+10													
90	35	21.0	+9				66.2	70.4	65.8	69.1	65.0	68.8	63.0	66.6	SCRUBBING	
95					1.8	0										T-95. DOOR OPENED 3"
100		36.1	+9	80											AT	
101																
105							64.2	67.9	63.0	68.2	65.4	67.9	61.9	66.4	SINK	
110		31.2	+7													
115		28.6	+8													T=115 GAS TURNED DOWN.
120	25	27.9	+7				65.3	68.8	66.6	68.6	65.8	68.6	64.4	67.5		
125				40												T-125 DOOR CLOSED.
131		54.2	+12			0										
135							67.7	69.1	69.9	72.2	68.6	72.6	65.5	67.7		
138		51.0	+7			0										
140				40												
145		59.0	+5													
150							67.9	72.0	68.8	72.2	67.1	70.9	65.0	67.9		T-150 DOOR OPENED 3"
152	65	51.5	+4													
153						0									WRINGING.	
155		20.2	+4													T-155 GAS TURNED OFF.
160				105												
165							66.0	68.8	64.6	68.8	64.4	68.6	63.8	61.1		T=165 DOOR CLOSED.
170		25.6	+4												WASHING AT SINK	
171						-2										
180	55	22.0	+4				65.8	67.0	64.6	69.3	64.2	68.8	63.8	61.1		
185				105											BOTH SUBJECTS TOOK LUNCH IN EXPERIMENTAL ROOM	
195							63.6	61.1	62.6	61.7	62.4	61.5	61.9	66.2		
200				40		-2										
205		10.3	+5													
210	75	10.4	+1				63.6	67.3	62.6	67.1	61.9	61.5	61.9	66.4		
214					0.6	-2										
220				100												
222		4.1	+2				64.0	67.7	63.0	68.4	62.6	68.2	61.1	66.2		
229					0.1	-4										
234		20.9	+2													
240	45						63.6	67.5	63.0	68.4	62.4	68.4	61.9	66.4	WASHING AT SINK.	
244		13.0	+2			-2										
245				85												
254		12.5	+2													
255						-2										
260				80												
266		55.4	+5													
267						-2									WRINGING	EXTERNAL:- W.B. 56.0°F; D.B. 60.0°F
270	55					-2	63.0	66.9	62.6	68.6	62.1	68.2	62.1	66.2		CORRIDOR:- W.B. 57.0°F; D.B. 64.0°F.
275		31.0	+5			-2										
280				95											HANGING OUT CLOTHES.	
285		26.0	+4			0										
292		27.1	+3													
300		19.3	+2	75			63.0	67.1	62.1	67.9	61.4	67.9	61.7	66.4		
305															SUBJECT C RESTING.	
314		10.6	-3													
320		6.0	-3	90												
330	70	12.0	-1.				62.4	66.0	61.4	67.5	60.9	67.1	60.9	65.8		

FULL-SCALE USER-TEST STUDIES.
Day 6. Subject C washing; Subject F control.
Ventilation by Right Hopper Window only.

PHYSICAL & PHYSIOLOGICAL DATA.

DAY:- 6 WORKING SUBJECT C, CONTROL SUBJECT F. } RIGHT HOPPER OPEN ONLY.

TIME	PHYSIOLOGICAL DATA:- SUBJECT C			SUBJECT F			PHYSICAL DATA:- W.B. & D.B. TEMPERATURES (°F)								NOTES Subjects procedure etc.
(MINS)	CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	ESTIMATED SENSATIONS OF HEAT + MOISTURE	CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	ESTIMATED SENSATIONS OF HEAT + MOISTURE	I_2 W.B.	I_2 D.B.	II_1 W.B.	II_1 D.B.	II_2 W.B.	II_2 D.B.	II_3 W.B.	II_3 D.B.	
0	75			95	1.0	-2									
20		0.4		80											
30	70		0				59.8	62.8	58.9	63.0	58.7	63.0	58.3	61.9	
32															
36		0.6	+1			-1									SORTING. EXTERNAL:- W.B. 54.0°F D.B. 58.0°F
40				90											CORRIDOR:- W.B. 56.0°F D.B. 60.0°F
41						-1									
45							60.5	63.8	60.3	64.6	60.3	64.4	58.3	62.1	
46		1.3	+2												
52		4.8	+5			0									
60	30						62.1	65.8	61.4	65.3	61.2	65.0	60.0	63.6	T=60 GAS WASH BOILER LIT
62		3.2	+5												
63				75		+1									
72		38.5	+12												
73					2.6	+2									WASHING
75							65.0	69.3	66.2	70.1	66.0	64.3	61.4	64.2	
80				80											INCLUDING
81		51.0	+14												
82						+3									SCRUBBING
86		45.3	+14												
87						+3									AT
89		57.2	+14												
90	20					+3	68.4	72.4	68.2	71.6	67.7	71.1	63.6	65.5	SINK
94		61.4	+14			+4									
100				65											
105						+5	69.7	74.0	70.1	74.4	70.1	73.8	64.4	66.2	
109		45.5	+14												
115		41.0	+14			+5									T=115 GAS TURNED DOWN
120	15						72.4	75.6	73.8	76.4	72.4	74.7	65.8	67.5	
122		41.0	+14		7.8	+6									
125				65											
126		26.1	+14												
132		32.3	+15			+8									
135					10.1	+8	73.8	75.2	73.0	74.7	72.2	73.8	65.8	67.5	
140		30.8	+7	75											
144		23.5	+7												
145						+8									
150	20	23.5	+8			+5	70.9	73.8	70.1	73.3	70.1	72.8	65.6	67.5	
151		15.6	+8			+4									T-155 GAS TURNED OFF.
160				75											WRINGING
162		14.4	+6												
165							70.1	72.4	64.0	72.0	64.0	71.8	65.6	67.1	
170		20.5	+8												WASHING AT SINK.
180	60	14.1	+8			+4	70.1	72.2	68.4	72.0	64.0	71.6	67.5	67.1	
185															BOTH SUBJECTS
195							68.5	71.6	68.0	71.8	68.0	71.3	67.4	68.1	TOOK LUNCH IN
210	65						67.0	71.0	67.5	71.2	67.0	71.0	67.0	68.1	ADJOINING ROOM.
213					2.2	+3									
215		69.5	+3												
220				90											
222		18.2	+5			+5									
225							67.5	70.8	67.2	71.2	67.2	71.0	66.4	68.3	WASHING AT SINK.
231		15.6	+6												
240	25						67.2	70.2	67.5	71.2	67.2	70.8	66.4	69.0	
243		1.6	+5			+3									
245				100											
249		9.1	+6			+3									
255		4.7	+7			+3									
260		20.8	+12	75		+4									EXTERNAL:- W.B. 57.0°F D.B. 62.0°F
270	40						67.0	71.0	66.5	70.3	66.2	70.5	65.0	64.0	WRINGING. CORRIDOR:- W.B. 58.0°F D.B. 64.0°F
272		1.0	+3												
280				75											HANGING OUT CLOTHES.
285		1.8	+5		4.2	+4									
295															
300	15				3.1	+1	64.6	64.8	66.6	71.1	65.3	70.2	64.5	69.1	
304		2.1	+2												SUBJECT C
305				85											
308					2.2	+1									RESTING.
309		1.5	+2												
315		2.8	+2			+1									
320				95											
325		1.6	+2			+1									
330	85						64.7	70.1	66.2	71.8	65.6	71.3	64.5	68.1	

FULL-SCALE USER-TEST STUDIES.
Day 7. Subject D washing; Subject C control.
Ventilation arranged by Subject D.

FULL-SCALE USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA.

DAY:- 7 WORKING SUBJECT D, CONTROL SUBJECT C } VENTILATION ARRANGED BY SUBJECT D.

TIME	PHYSIOLOGICAL DATA:- SUBJECT D CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	SUMMATED SENSATIONS OF HEAT + MOISTURE	SUBJECT C CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	SUMMATED SENSATIONS OF HEAT + MOISTURE	PHYSICAL DATA W.B. & D.B. TEMPERATURES (°F) I 2 W.B.	D.B.	I 1 W.B.	D.B.	II 2 W.B.	D.B.	II 3 W.B.	D.B.		NOTES subject's procedure etc.
(MINS).																
0	90			80												
15					1.1	0										
16		0.7	-3													
20				80												
25																
26		1.3	-2		0.8	+1										EXTERNAL:- W.B. 58.0°F, D.B 60.0°F CORRIDOR:- W.B. 58.0°F D.B 61.0°F
30	105						60.7	64.4	59.8	64.0	59.8	64.0	59.8	62.1		
31		1.3	-3												SORTING.	
35						+1										
36		0.6	-5													
40				95												
41		1.4	-1													
45					0.6	-2	60.7	64.0	60.3	64.6	60.3	64.4	58.9	61.1		
46		1.0	-2													
51		0.4	0													
56		0.3	+1													
57					1.2	+3										
60	75						64.2	68.4	61.1	65.8	62.1	65.6	60.3	63.6		T=60 GAS WASH BOILER LIT
66		0.6	+3	95		+4										
67																
71		0.4	+2												WASHING	
75							65.5	64.3	67.1	71.5	66.6	70.1	62.4	63.0		T=75. RIGHT CASEMENT WINDOW HALF-OPENED
77		0.5	+2		0.1	+5									INCLUDING	
80				95												
84		0.4	+3												SCRUBBING	
90	60				0.6	+3	68.8	72.8	68.8	70.0	68.6	71.6	64.4	65.8		
93		1.0	+3												AT	
95						+4										
99		6.3	+9												SINK.	
100				90												
105							68.8	73.3	70.9	73.0	64.0	69.9	63.0	65.8		T=105 LEFT CASEMENT WINDOW FULLY OPENED.
106		7.3	+7													
115		1.0	+10		2.0	+7										
120	70						68.8	72.0	70.1	72.8	68.8	69.1	64.8	65.8		T=120 GAS TURNED DOWN.
122						+5										
125		4.5	+8	70												
130		2.9	+9													
133						+5										
135		12.7	+8				64.3	72.4	66.2	69.0	64.8	68.4	64.4	65.3		T=135 DOOR FULLY OPENED.
140				80												
145		6.2	+8		2.9	+2										
150	60						64.4	61.1	64.4	61.1	64.2	66.6	63.6	66.2		T=150 GAS TURNED OFF.
154		8.0	+3													
158						-2										
160			+4	95												
161		6.2				-3										
165							64.4	64.8	62.1	64.8	61.2	64.4	62.6	64.6		
171		5.3	+1													
172						-4									RINSING	
180	60						63.6	65.8	61.1	66.2	62.1	66.2	63.0	64.8		T=180 DOOR CLOSED.
184					2.9	-6										
185		1.2	-3	80											BOTH SUBJECTS TOOK LUNCH IN EXPERIMENTAL ROOM.	
195							64.4	61.5	64.4	61.9	64.0	61.9	62.6	64.8		
200																
210	75			85			64.6	61.5	64.0	61.9	64.2	61.5	63.3	64.8		
220				85												
225		1.5	-3				65.3	68.4	64.4	68.8	64.4	68.6	63.3	64.6		
227					2.9	+1										
235		0.9	0			+2										
240	50					+2	65.8	68.8	64.8	68.8	64.6	68.4	63.6	65.5		
243		1.3	+2													
245				95												T=245 RIGHT CASEMENT WINDOW ALMOST FULLY OPENED.
255		1.4	-3			-1									WRINGING	
260	70	0.6	-1	90	3.1	-2										
270		0.6	+2				64.6	61.1	64.4	68.8	64.4	67.1	63.6	65.3		
274						-2										EXTERNAL:- W.B. 59.0°F D.B. 60.0°F CORRIDOR:- W.B. 60.0°F D.B. 61.0°F. (RAINING).
280				85												
281		0.3	0													
295		0.6	+1			+2									HANGING OUT CLOTHES.	
300	70						64.6	61.9	64.4	68.8	64.4	68.4	64.0	65.3		
303		1.1	-2													
305				95		+2									SUBJECT D RESTING.	
315		2.0	-3			-2										
320				90												
330	80						64.4	61.1	64.4	68.8	64.4	67.9	62.6	65.3		

FULL-SCALE USER-TEST STUDIES.
Day 8. Subject D washing; Subject C control.
Ventilation by Right Hopper Window only.

FULL-SCALE USER-TEST EXPERIMENTS.

PHYSICAL & PHYSIOLOGICAL DATA.

DAY:- 8 WORKING SUBJECT D / CONTROL SUBJECT C } RIGHT HOPPER OPEN ONLY.

TIME	PHYSIOLOGICAL DATA: SUBJECT D: CRAMPTON INDEX	SUBJECT D: FOREHEAD SKIN CONDUCTIVITY OHMS^{-1} ×10^{-6}	SUBJECT D: SUMMATED SENSATIONS OF HEAT + MOISTURE	SUBJECT C: CRAMPTON INDEX	SUBJECT C: FOREHEAD SKIN CONDUCTIVITY OHMS^{-1} ×10^{-6}	SUBJECT C: SUMMATED SENSATIONS OF HEAT + MOISTURE	PHYSICAL DATA. W.B. & D.B. TEMPERATURES (°F): I_1 W.B	I_1 D.B	II_1 W.B	II_1 D.B	II_2 W.B	II_2 D.B	II_3 W.B	II_3 D.B	NOTES. Subjects procedure etc.
(MINS)															
0	90		-8		4.3	+1									
5				75											
8						+2									
15			-4												
18						+3									
20			-4	85											
25			0												
30	85		-3		0.8	+1	59.8	61.7	58.9	63.0	58.5	62.6	57.1	60.3	SORTING. EXTERNAL:- W.B 56.0°F D.B. 56.0°F
34						+1									CORRIDOR:- W.B. 56.0°F. D.B 54.0°F
35			-2												
40				85											
45			0			0	59.8	67.1	59.3	63.6	59.8	63.0	57.6	60.7	
50			0			+1									
55			+1												
60	65						60.9	64.4	59.8	64.2	60.3	63.6	59.8	62.1	T=60 GAS WASH BOILER LIT.
65				85											
67			0			+2									
70															
75			+2			+3	64.4	61.9	64.8	68.8	64.8	68.8	60.7	62.6	
80				85											
85			+7			+6									
90							[illegible]	72.4	68.6	63.0	67.9	70.1	63.6	64.4	WASHING
95	45		+2												
96					1.5	+5									INCLUDING
100			+1	85											
102						+4									SCRUBBING
105							68.8	72.4	69.7	73.8	68.8	72.8	63.6	64.4	
107			+9												AT
109						+6									
112			+9												SINK.
118					0.7	+6									
120	30						70.1	73.2	68.8	72.8	68.4	71.1	64.4	65.3	T=120 GAS TURNED DOWN.
125			+10	80											
130			+10												
135							73.3	75.2	73.3	75.2	72.8	73.3	66.6	66.6	
140			+8	85		+6									
145		12.0	+8		2.1	+6									
150							73.3	76.4	73.3	76.0	73.3	74.2	65.3	67.9	T:150 GAS TURNED OFF
152	45	27.6	+11												
155						+6									
160		25.0	+12	75		+8									
162															
165		14.6	+10				73.3	74.2	74.2	74.7	73.0	73.3	65.8	61.5	
167						+8									
170		25.0	+10												RINSING
176		36.4	+11												
179						+7									
180	40						73.3	74.0	73.5	74.7	72.0	73.8	66.2	67.9	
186				85											
191					3.2	+3									BOTH SUBJECTS
196							71.0	71.5	70.5	72.2	68.0	70.8	65.1	65.9	TOOK LUNCH IN
200				75											EXPERIMENTAL ROOM.
210	50	2.5	+3				68.8	69.7	67.5	69.7	66.2	69.3	64.0	65.8	
218		1.5	0												
220				75											
225		7.7	0			0	68.4	69.3	66.6	69.3	66.2	68.8	64.4	65.8	
230		2.4	0			+1									
235		2.5	0			0									
240	50						67.9	69.3	66.6	69.7	66.2	68.8	64.4	66.6	
245		4.5	0	85											
249						+1									
253		1.7	+3												WRINGING
259		3.5	+5			+3									
260				85											
270	25	9.8	-2		0.1	+5	67.1	68.8	66.2	69.3	65.3	68.8	64.4	66.2	
273		3.5	-2												EXTERNAL: W.B 53.0°F D.B 54.0°F
275						+3									CORRIDOR: W.B. 51.0°F D.B. 63.0°F
280				75											
285		8.5	+5			+3									
295		6.0	+7			+1									HANGING OUT CLOTHES.
300	45						64.8	67.5	64.8	68.4	64.0	67.9	63.0	64.8	
305		1.5	0	85		+1									
315		3.4	+5		1.8	+2									SUBJECT D
320		2.1	+1	85											RESTING
326						+1									
330	75					+1	65.3	68.8	64.8	68.8	64.4	67.9	64.0	65.3	

Protocols of Controlled Laboratory Experiments carried out to test the correlation between the physiological indices employed in the User-Test studies and changes in environmental thermal conditions.

Experiments on working and resting subjects in an air-conditioned laboratory at the London School of Hygiene and Tropical Medicine.

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 1. Resting.
Relative humidity approximately 60%

SUBJECT NO. 1								
TIME	CRAMPTON INDEX	THERMAL SENSATION	WHIRLING HYGROMETER			GLOBE THERMO.	SILVERED THERMO.	AIR VEL
(MINS)		H. M. F.	W.B. °F	D.B. °F	R.H %	°F	°F	ft/min
0			57.0	68.0	68			100
4		-3 -2 -1						
10			62.0	70.0	65			
14		-3 -2 -1						
25	75	-3 -2 -1	65.0	72.5	61	71.0	71.0	90
34			67.0	76.0	65			
40	80	+1 0 0	68.0	77.0	61	72.8	76.2	
45		+1 0 0	70.0	80.0	62			
52	85	+1 0 0	71.5	82.0	62	77.4	82.0	210
56		+1 +1 0						100
63	65	+2 +1 0	73.0	83.0	63	80.8	82.6	
67			74.0	84.0	63			
72		+2 +2 0	74.0	85.0	60	83.0	84.6	
82	15	+2 +2 0	75.0	86.0	60	85.6	85.0	225
90			76.0	87.0	60	85.4	85.6	165
92								
109	10	+4 +3 +1	78.5	88.0	60	86.6	87.2	120
110			77.0	88.0	61			
123	10	+4 +3 +1	78.0	87.0	61	87.6	88.2	135
130			77.0	90.0	62			
138	65	+4 +3 +2	77.0	89.0	63	88.2	87.0	185
150	15	+4 +3 +2	80.0	91.0	62	87.1	90.0	110
168		+4 +3 +2	81.0	91.0	64			
180	15	+4 +3 +2	81.0	92.0	64	90.2	91.2	165
192			82.0	93.0	64			
194	70	+6 +5 +2	82.0	92.5	64	90.8	92.5	145
204		+6 +5 +2	83.0	94.0	63	91.5	92.5	195
220			84.0	95.0	64			
225	45	+7 +6 +2	85.0	96.0	63	94.4	96.2	65
232	25	+7 +6 +2	86.0	97.0	60	100.0	97.4	65
240	30	+7 +7 +2	86.0	97.0	60	100.0	97.4	

NOTES.

Subject at rest throughout experimental period.

No measurements of air velocity were made as the apparatus used was not in working order.

Visible sweat on subject's forehead.

CONTROLLED LABORATORY EXPERIMENTS.
Subject No. 1. Resting.
Relative humidity approximately 80%

TIME (MINS)	SUBJECT NO:- 1 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B. °F	D.B. °F	R.H. %	GLOBE THERMO °F	SILVERED THERMO °F	AIR VEL ft/min	NOTES
-20	75	1.40	-2 -2 -2	66.0	70.0	81	70.0	69.6	48	
-10	75			61.5	71.0	84	70.6	70.3	56	
-5			-2 -2 -2	68.0	71.0	86	70.9	70.6	52	
+8	75		-2 -2 -2	68.0	71.0	86	71.5	71.2	40	ZERO →
9		1.17								
16			-3 -2 -2	68.5	71.5	86	71.7	71.4	46	
24	80			70.0	74.0	82	72.1	73.3	65	
25		1.76	-2 -2 -2							
32			-2 -2 -2	72.0	77.0	79	74.8	77.2	51	
35		4.09								
40	75		-2 -2 -2	73.0	77.5	81	75.8	77.0	50	
41		1.16								
48			-1 -1 -2	73.0	76.0	87	76.9	76.7	41	
55		1.89								
56	70			75.0	80.5	78	77.8	79.7	60	
57		1.52	-1 -2 -2							
64			-1 -1 -1	75.0	77.0	83	79.1	79.4	60	
72	70		-1 -1 -1	75.5	80.0	81	79.8	80.1	62	
73		1.28								
80			-1 -1 -1	75.0	80.0	79	80.0	79.1	68	
87										
88	60		0 0 -1	76.0	81.0	80	80.1	80.7	55	
89		5.85								
96			0 0 0	78.0	83.0	80	82.6	83.8	55	
100		1.81								
104	55		+1 0 0	78.5	83.0	82	83.2	83.4	51	
105		4.33								
112			+1 0 0	78.0	83.5	82	83.8	84.2	55	
115		2.04								
120	55			80.5	86.5	77	84.4	86.0	51	
121		2.80								
128			+1 +1 +1	80.5	85.5	81	85.1	86.2	60	
135	50		+2 +1 +1	81.0	85.5	83	85.4	86.1	80	
144		2.80	+2 +1 +1	81.5	86.0	82	86.2	86.4	58	
147		3.04								
152	45		+3 +2 +1	83.0	88.0	81	86.8	88.6	65	
155		3.63								
160			+3 +2 +1	84.0	90.0	78	88.6	89.4	57	

TIME (MINS)	SUBJECT NO:- 1 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B. °F	D.B. °F	R.H. %	GLOBE THERMO °F	SILVERED THERMO °F	AIR VEL† ft/min
163		1.99							
168	50		+3 +2 +1	85.0	90.0	81	89.4	90.1	58
169		6.08							
176			+4 +3 +2	87.0	93.0	79	90.8	93.4	65
180	50								

† Subject at rest throughout the experimental period.

CONTROLLED LABORATORY EXPERIMENTS.

Subject No. 1. Step-Climbing

Relative humidity approximately 60%

	TIME	SUBJECT NO:-1			WHIRLING HYGROMETER					
		CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY	THERMAL SENSATIONS	W.B.	D.B.	R.H.	GLOBE THERMO.	SILVERED THERMO.	AIR VEL.
	(MINS)		OHMS⁻¹ x10⁻⁶	H. M. F.	°F	°F	%	°F	°F	ft/min
	-20	95	2.22	-2 -2 -2	61.5	68.0	69	67.0	67.4	35
	-12	95	1.29		63.0	70.0	68	67.0	67.0	
	-5		1.27		64.0	70.0	72	67.5	67.4	85
	-4	90			64.0	70.0	75	67.7	67.6	61
ZERO →										
	+3		0.93							
E(9) →	12		0.82	-2 -2 -2						
	16	85			65.0	71.0	73	70.4	70.4	140
	18		3.16							
E →	22		2.81							
	26		3.14	0 0 0	67.0	78.0	64	75.2	77.4	
	32	75		+1 0 0	71.5	80.5	65	77.4	80.6	42
	36		0.82							
E	40			+1 0 0	72.0	81.0	65	77.2	81.8	
	43		5.12						81.4	88
	45			+2 0 +1	72.0	80.0	68	79.2	80.2	
	48	75		+2 0 +1					80.0	60
	52		4.80							
E	56				73.0	83.0	62	82.0	83.6	40
	59		4.15	+2 0 +1						
	62		4.10	+2 0 +1						
	64	65		+2 0 +1	74.0	84.0	63	82.2	84.4	15
	70		4.10		75.0	85.0	63	83.4	85.3	
E	72				75.5	85.5	63	84.1	86.0	54
	75		10.5	+2 +1 +1						
	77		2.24							
	80	75	2.44	+2 +1 +1	77.0	87.0	64	85.2	86.8	50
	85		3.63	+2 +1 +1						
E	88				76.0	86.0	64	86.0	86.5	70
	90		4.48	+2 +1 +1						
	92		1.40							
	96	65		+2 +1 +1	77.0	87.0	64	86.0	86.5	45
	100		2.57	+2 +1 +1						
E	104			+2 +1 +1	78.0	87.0	62	87.7	87.4	60
	106		5.60							
	109		4.76							
	112	65	5.92	+3 +2 +1	79.0	90.0	62	88.4	90.1	55
	116		4.48							
E	120				80.0	90.0	65	87.0	90.8	50
	122		11.9	+4 +2 +1						
	125		8.10	+3 +1 +1						
	128	75	1.28		80.0	91.0	62	89.8	91.2	53
	132		7.70	+3 +2 +1						
E	136			+3 +2 +1	81.0	91.0	65	90.4	92.0	58

NOTES.	TIME	SUBJECT NO:-1			WHIRLING HYGROMETER					
		CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY	THERMAL SENSATIONS	W.B.	D.B.	R.H.	GLOBE THERMO.	SILVERED THERMO.	AIR VEL.
	(MINS)		OHMS⁻¹ x10⁻⁶	H. M. F.	°F	°F	%	°F	°F	ft/min
	138		17.7	+3 +2 +1						
	141		14.9							
	144		16.3	+3 +2 +1	81.0	91.0	65	91.0	92.0	65
	147		10.4	+3 +2 +1						
E	152				82.0	92.0	66	91.4	92.9	90
	154		28.3	+5 +2 +1						
	157		24.4	+4 +3 +1						
	160	50	20.8	+4 +3 +1	82.0	93.0	63	91.8	93.5	52
	164		20.3		83.0	93.0	66	92.2	93.6	50
E	168									
	170		33.8	+4 +3 +1						
	172		40.3	+5 +4 +1						
	176	55	31.2	+5 +4 +1	83.0	93.0	66	92.6	93.7	41
	180		25.1	+5 +4 +1						
E	184				83.0	94.0	63	93.0	94.1	40
	186		48.1	+5 +5 +1						
	190		55.5	+5 +5 +1						
	192	40	41.1		84.0	94.0	66	93.3	94.4	45
	195		42.[illegible]	+5 +5 +2						
	197		49.1	+5 +5 +2						
E	200				84.0	94.0	66	93.6	94.9	11
	202		56.1	+6 +5 +2						
	204		57.2	+6 +5 +2						
	208	55	41.6	+6 +5 +2	84.0	94.0	66	93.8	94.8	30
	212		51.8	+6 +5 +2						
	215			+6 +5 +2						
E	216		55.4		85.0	96.0	61	94.8	96.9	50
	218		57.8	+6 +5 +2						
	222		49.3	+6 +6 +2						
	224	15	46.7		87.0	98.0	64	97.2	99.4	30
	228		27.8							
	230		56.9	+6 +6 +2						
E	232				88.0	101.0	60	104.[illegible]	105.0	25
	234			+7 +7 +2						
	237			+7 +7 +2						
	240	20		+7 +7 +2	89.0	102.0	60	108.2	104.8	30

Subject resting for [illegible] minute periods. Time of commencing exercise indicated by "E" on left of each table.

VOTES.

Visible sweat on subject's face

CONTROLLED LABORATORY EXPERIMENTS.
Subject No. 1. Step-Climbing.
Relative humidity approximately 80%

	TIME (MINS)	SUBJECT NO:-1 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	THERMAL SENSATION H. M. F.	WHIRLING HYGROMETER W.B. °F	D.B. °F	R.H. %	GLOBE THERMO °F	SILVERED THERMO. °F	AIR VEL. ft/min	NOTES.
	-20	85	5·03		65·0	69·0	81	68·2	68·0	185	
	-10		7·14		66·0	70·0	81	69·0	69·0	320	
E(7) →	-5	80		-1 -1 -1	67·0	70·0	86	69·8	69·8	220	
→	8				68·5	72·5	86	70·4	70·8	150	
	9		5·15	-1 -1 -1							
E(23) →	16	70		-2 -2 -1	68·5	72·5	84	72·0	71·6	270	
	24				72·0	77·0	79	73·0	75·8	160	
	25		3·74	+1 0 0							
E(39) →	32	75	1·76	+1 0 0	73·0	77·0	83	75·9	79·0	220	
	40				74·0	78·0	83	77·4	78·5	190	
	41		2·22	+1 0 0							
	45										
	48	65		+1 0 0	75·0	78·0	87	78·2	78·4	190	
E	53		3·16		76·0	80·5	82	78·8	80·2	200	
	57		5·50	+2 +1 0							
	64	50			76·5	80·5	84	80·6	81·0	235	
	65			+2 +1 0							
E	71		3·16		77·0	82·0	80	81·2	82·0	255	
	73		7·37	+3 +1 0							
	75										
E(87) →	80	35	3·74	+2 +1 0	77·0	81·0	84	81·4	81·2	160	
	88				78·0	81·5		81·8	81·7	215	
	89		11·6	+3 +2 +1							
	96	35		+3 +2 +1	79·0	83·0	84	83·2	83·9	205	
E(103) →	100		5·38								
	104				80·0	84·0	84	83·4	84·0	215	← Visible sweat on subject's forehead.
	105		26·7	+3 +2 +1	74·5	82·0	86				
	112	40	15·0	+4 +2 +1	79·5	83·0	80	83·8	83·8	125	
	117				82·0	87·0	81	84·6	87·0	160	
E	119		43·2	+5 +3 +1							
	124				82·5	88·0	80	87·0	89·2	210	
	128	25									
E(135) →	130		25·2	+5 +4 +1							
	136				83·0	88·0	81	87·5	88·6	145	
	138		21·7	+5 +5 +2							
	140										
	148		26·8								
E(151) →	150	25		+5 +4 +1	85·0	90·0	81	88·6	91·0	250	
	153		37·2	+5 +5 +1							
	157		38·1								
	160	30			86·0	92·0	78	90·4	92·8	175	
	162			+5 +5 +2							
E	167										

	TIME (MINS)	SUBJECT NO:-1 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	THERMAL SENSATION H. M. F.	WHIRLING HYGROMETER W.B. °F	D.B. °F	R.H. %	GLOBE THERMO °F	SILVERED THERMO. °F	AIR VEL ft/min
	168				88·0	93·5	80	92·0	94·4	175
	169		+3·3	+6 +5 +2						
	175			+6 +6 +2						
	176	25			89·0	94·0	82	93·6	95·4	225
E(183) →	180		69·3	+6 +6 +2						
	184				90·0	95·0	82	94·0	96·1	190
	187		118	+6 +6 +2						
	192	20			90·5	95·5	82	95·2	97·1	165
	196		102	+7 +7 +2						
E	199				91·0	96·0	83	96·0	97·7	150
	201		99·6	+7 +7 +2						
	208	20			91·0	96·0	83	96·4	98·0	175

Subject resting for two minute periods
Line of commencing exercise indicated by E in column left of each table.

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 2. Step-Climbing.
Relative Humidity approximately 80%

	TIME (MINS)	SUBJECT NO:- 2 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY $OHMS^{-1} \times 10^{-6}$	THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B. °F	D.B. °F	R.H. %	GLOBE THERMO °F	SILVERED THERMO °F	AIR VEL. ft/min	NOTES
	-20	65	2.11	-1 0 -1	65.0	69.0	81	67.8	67.3	135	
	-10	75		+1 0 0	66.0	70.0	81	67.8	67.5	135	
	ZERO		1.05	+1 0 0	67.0	70.0	86	70.0	67.7	160	
E	+7		1.87	0 -1 -1							
	8				68.0	71.0	86	70.7	70.7	150	
	9		1.40	0 -1 -1							
E(23) →	16	75		0 -1 -1	68.0	71.0	86	71.0	70.9	145	
	24				70.0	76.0	78	71.9	74.4	135	
	25		2.46	0 -1 -1							
E(39) →	32	60		+1 0 0	72.0	77.5	77	75.6	77.6	110	
	40			+1 0 0	73.0	78.0	74	77.2	77.8	115	
	41		1.64	+1 0 0							
	48	45			73.0	77.5	81	76.3	77.5	110	
E	55		3.51	0 0 0							
	56				73.5	79.0	77	77.9	78.8	140	
	57		4.68	+1 0 0							
	64	45		+1 +1 0	75.0	80.0	79	79.7	80.6	120	
E	71			+1 +1 0							
	72				75.5	80.5	80	80.3	80.8	135	
	73			+1 +1 0							
	80	40		+1 +1 0	76.0	80.0	83	80.4	80.4	150	
E	81		3.74	+1 +1 0							
	88				77.0	80.0	87	80.8	80.0	140	
	89		5.03	+1 +1 0							
	96	30		+2 +1 0	79.0	85.0	77	81.8	84.4	165	
E	103		12.4	+2 +2 0							
	104				79.5	84.5	81	83.6	84.2	140	
	105		12.4	+2 +2 0							
	112	30		+2 +2 +1	79.5	83.0	86	83.8	83.3	135	
E	119			+2 +2 +1							
	120				80.0	84.5	82	84.1	84.2	160	
	121		11.7	+2 +2 +1							
	128	30		+2 +3 +1	82.0	88.0	78	85.3	87.7	160	
E	135		19.7	+3 +4 +1							
	136				82.0	87.0	81	87.0	87.2	160	
	137		25.4	+3 +4 +1							← Visible sweat on Subject's forehead.
	144	25		+3 +4 +1	83.0	88.5	80	87.4	88.6	145	
E	151		35.5	+4 +5 +1							
	152				85.0	92.0	75	89.2	91.5	140	
	153		41.6	+4 +5 +1							
	156										
	160	15		+4 +5 +1	85.0	90.0	81	90.8	90.6	155	
E	167		45.9	+4 +5 +1							
	168				86.0	92.0	78	90.9	92.2	140	
	169		72.7	+4 +5 +1							
	170										
	176	15		+5 +5 +2	85.0	90.0	81	90.9	91.0	150	
E	183		45.0	+5 +5 +1							
	184				87.5	93.5	79	91.7	93.6	150	
	185		64.1	+5 +5 +2							
	192	15		+4 +5 +2	90.0	95.0	83	93.7	95.8	150	
E	199		78.8	+5 +5 +2							
	200				91.0	96.0	83	95.0	96.8	145	
	201		43.3	+6 +5 +2							
	208	10		+6 +6 +2	92.0	97.0	83	96.1	97.7	155	
E.	215		101								
	216			+6 +6 +2	93.0	98.0	83	96.8	98.0	135	
	217		14.7	+6 +6 +2							
	224	-10		+6 +6 +2	93.0	98.0	83	97.3	98.8	205	

Subject exercising in two minute periods.
Line of commencing exercise indicated by E on column left of each table.

NOTES.

CONTROLLED LABORATORY EXEERIMENTS

Subject No. 3. Resting.

Relative humidity approximately 80%

TIME (MINS)	SUBJECT NO:- 3 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY $OHMS^{-1} \times 10^{-6}$	THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B. °F	D.B. °F	R.H. %	GLOBE THERMO. °F	SILVERED THERMO. °F	AIR VEL. ft/min
-15	75		-3 -2 -1	67.0	11.0	82	10.8	64.8	185
-5	75	1.60	-2 -1 0	67.0	10.0	86	10.8	70.0	190
ZERO									
+8	50			68.0	72.0	82	12.2	71.7	260
18		11.70	-2 -2 0						
24	55	5.85	0 +1 0	12.0	18.0	15	14.0	11.8	[illegible]
40	55	2.70		15.0	80.0	74	14.0	74.8	[illegible]
47		5.40	+1 +2 0	15.0	80.0	79	14.1	80.2	-65
56	55	4.50	+2 +2 0	76.5	80.5	84	80.2	80.2	270
72	60	4.50	+2 +2 +1	11.0	81.0	84	81.1	80.6	240
88	50		+2 +2 0	77.0	81.0	84	81.3	81.2	255
95		4.50							
104	35		+2 +2 +1	80.0	85.0	81	84.2	85.8	240
109		2.70							
112		4.05	+2 +2 +1						
120	35	5.85	+3 +2 +1	82.5	84.5	75	86.3	88.6	240
136	30	12.10	+3 +3 +1	82.0	88.0	75	88.3	88.5	225
145		13.6	+3 +3 +1						
152	35	11.8	+5 +5 +2	84.5	91.0	77	90.0	90.2	210
160		12.5	+5 +5 +2						
168	15	21.2	+5 +5 +2	86.0	92.0	78	91.2	91.4	215
176		51.0	+6 +5 +2						
184	15	79.5	+6 +5 +2	87.5	92.5	82	91.8	92.8	345
192		87.5	+6 +5 +2						
200	5	72.0	+6 +6 +2	91.0	96.0	83	94.6	96.5	310
208		65.0		92.0	97.5	81			
216	10	83.2	+6 +6 +2	92.0	97.5	81	96.2	97.8	345
220		71.1	+6 +6 +2	92.0	98.5	77			
226				93.0	100.0	77	97.2	98.8	430
230		70.3		93.0	100.0	77	92.6	99.0	
234		86.6	+7 +7 +2						

NOTES.

Subject resting throughout experimental period

Visible sweat on forehead of subject

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 5. Step-Climbing.
Subject No. 3. Resting.
Relative humidity approximately 60%.

	TIME (mins)	Subject No. 5 Lampton Index	Subject No. 5 Forehead Skin Conductivity ohms^{-1} x10^{6}	Subject No. 5 Thermal Sensations H. M. F.	Subject No. 3 Lampton Index	Subject No. 3 Forehead Skin Conductivity ohms^{-1} x10^{6}	Subject No. 3 Thermal Sensations H. M. F.	Whirling Hygrometer W.B. °F	Whirling Hygrometer D.B. °F	R.H. %	Globe Thermo °F	Shielded Thermo °F	Air Vel. ft/min
	-20	85		-4 -1 0			-3 -2 -1	53.0	63.5	52	62.6	61.7	400
	-15			-3 -1 0	10		-2 -1 0	54.0	64.0	52	6[illegible].1	63.5	420
	-5	85	2.40			1.16		56.0	66.0	53	64.1	64.7	520
	Zero			-3 -1 -1	10		-2 -1 0	56.5	66.0	55	65.0	65.6	530
E	+1		3.57	-3 -1 -1									
	8				10		-2 -1 0	58.0	67.0	58	66.0	66.6	410
	9		5.60	-1 -1 0									
	16	85		-3 -1 0		5.00	-2 -1 0	58.5	67.5	58	66.7	67.2	425
E	23		6.80	-3 -1 0									
	24				10		-1 -1 0	59.0	68.0	59	67.3	67.6	600
	25		5.12	-1 -1 0									
	32	75		-3 -1 0		2.40	-1 0 0	60.0	68.0	63	67.8	68.0	600
E	39		1.00	-3 -1 0									
	40				70		-1 0 0	65.0	73.5	63	67.0	71.8	540
	41		3.20	0 -1 0									
	48	70		-2 -1 0		1.13	+1 +1 0	67.0	76.5	61	72.4	75.6	4[illegible]0
E	55		5.00	0 -1 0									
	56				60		+1 +1 0	68.5	78.0	62	75.5	77.8	540
	57		1.20	+1 0 0									
	64	65		+1 0 +1		2.40	+1 +1 +1	67.0	78.5	62	77.0	78.6	410
E	71		4.02	+1 0 +1									
	72				65		+1 +1 +1	70.0	79.0	64	77.7	78.0	4[illegible]0
	73		7.15	+1 0 +1									
	80	60		+2 0 +1		5.15	+1 +1 +1	70.0	78.5	66	78.0	78.2	450
E	87		5.20	+1 +1 0									
	88				60		+1 +1 +1	72.0	81.5	64	79.4	81.2	450
	89		5.60	+1 +1 +1									
	96	65		+2 0 +1		5.40	+2 +1 +1	72.0	82.0	62	80.5	81.9	470
E	103		6.00	+2 0 +1									
	104				60		+2 +1 +1	73.0	83.0	62	81.6	83.0	470
	105		5.60	+2 +1 +1									
	112	65		+2 +1 +1		6.00	+2 +1 +1	73.5	83.5	62	82.6	83.7	580
E	119		8.20	+2 +1 +1									
	120				50		+2 +1 +1	74.0	84.0	63	83.1	84.0	560
	121		7.45	+3 +2 +1									
	128	55		+3 +2 +1		6.40	+1 +1 +1	75.0	85.0	63	84.0	84.8	565
E	135		8.80	+3 +2 +1									
	136				50		+2 +1 +1	75.0	85.5	62	84.6	85.7	520
	137		6.40	+3 +2 +1									
	144	55		+3 +3 +1		2.60	+1 +1 +1	75.5	86.0	62	85.3	85.8	510
E	151		4.40	+3 +3 +1									
	152				40		+2 +1 +1	76.0	86.5	64	85.8	87.0	560
	153		5.37	+3 +3 +1									
	160	50		+4 +4 +1		5.74	+1 +1 +1	77.0	87.0	64	86.3	87.1	540
E	167		5.60	+3 +4 +1									
	168				40		+1 +1 +1	77.0	88.0	61	86.7	87.6	480
	169		4.20	+3 +4 +1									
	176	50		+3 +4 +1		5.20	+1 +1 +1	77.5	88.0	62	87.1	87.7	580
E	183		12.1	+4 +4 +1									
	184				35		+2 +1 +1	79.0	90.0	62	88.7	90.2	400
	185		9.53	+5 +4 +1									
	192	40		+5 +4 +1		5.74	+2 +1 +1	80.0	91.0	65	92.0	92.1	455
E	199		10.4	+4 +4 +1									
	200				35		+3 +2 +1	81.0	92.0	63	94.1	93.6	430
	201		21.1	+5 +4 +1									
	208	35		+5 +4 +1		8.10	+3 +2 +1	82.0	93.5	62	95.5	94.3	400
E	215		19.8	+5 +4 +1									
	216				35		+4 +3 +1	82.5	94.0	61	96.3	94.7	560
	217		26.0	+5 +5 +1									
	224	25		+5 +5 +2		8.80	+4 +3 +1	83.0	94.0	63	96.5	95.1	440
E	231		25.9	+5 +5 +2									
	232				15		+4 +3 +2	84.0	96.0	61	98.8	97.3	350
	233		40.7	+6 +5 +2									
	240	15	39.0	+6 +5 +2		13.1	+4 +3 +2	85.5	98.0	60	101.8	98.7	345

NOTES

Subject No. 5 [illegible] for [illegible] minute [illegible]. Time of commencing [illegible] indicated by "E" on [illegible] left of table.

Visible sweat on forehead of Subject No. 5. (at 231 mins)

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 6. Step-Climbing.
Subject No. 4. Resting.
Relative humidity approximately 60%

NOTES.

Subject No 6 Exercising for two minute periods. Time of commencing exercise indicated by "E" in column left of table.

	Time (Mins)	Subject No. 6 Crampton Index	Subject No. 6 Forehead Skin Conductivity ohms⁻¹ x10⁻⁶	Subject No. 6 Thermal Sensation H M F	Subject No. 4 Crampton Index	Subject No. 4 Forehead Skin Conductivity ohms⁻¹ x10⁻⁶	Subject No. 4 Thermal Sensations H M F	Whirling Hygrometer W B °F	Whirling Hygrometer D B °F	R H %	Globe Thermo °F	Silvered Thermo °F	Air Vel ft/min
	-20	85		-1 -1 -1			-2 -1 -1	61.0	68.5	65	67.5	67.9	500
	-15			-1 -1 -1	75		-2 -1 -1	62.0	69.0	68	68.2	68.8	465
	-5	80		-1 -1 -1			-3 -1 -1	62.5	70.0	66	68.8	69.3	545
	Zero			-2 -1 -1	75	5.40	-4 -1 -1	63.0	71.0	64	69.6	69.7	475
E	+7		0.93	-2 -1 -1									
	8				65		-4 -1 -1	64.0	71.0	69	70.2	70.4	555
	9		4.40	-1 -1 -1									
	16	75		0 -1 -1		4.60	-3 -1 -1	65.5	72.0	71	70.8	71.8	540
E	23		3.39	0 0 0									
	24				65		-1 -1 -1	71.5	79.0	70	74.8	78.0	605
	25		5.08	0 0 0									
	32	70		0 0 +1		6.77	-1 -1 -1	73.5	81.5	69	77.6	80.3	610
E	39		6.06	0 0 +1			0 -1 -1						
	40	.					0 -1 -1	74.5	83.0	61	80.2	82.6	745
	41		1.41	0 0 0	55								
	48	65		0 0 0		2.70	+1 0 0	75.0	85.0	63	82.1	84.2	680
E	55		4.40	+1 +1 +1									
	56				40		+1 0 0	76.0	81.5	60	84.0	85.9	780
	57		2.40	+1 +1 +1									
	64	55		+1 +1 +1		4.40	+1 0 0	76.5	87.5	61	85.9	87.6	845
E	71		1.54	+1 +1 +1									
	72				35		+1 0 0	76.0	88.0	58	86.8	88.2	555
	73		2.60	+1 +1 +1									
	80	50		+1 +1 +1		8.60	+2 +1 0	77.5	90.0	57	87.8	89.2	615
E	87		3.11	+1 -1 +1									
	88				30		+2 +1 0	78.0	90.5	57	88.9	90.0	650
	89		3.14	+1 -1 +1									
	96	40		+2 -1 +1		5.85	+3 +2 +1	78.5	91.0	58	89.8	91.4	770
E	103		4.50	+2 -1 +1									
	104				25		+3 +2 +1	79.5	92.0	58	90.4	91.7	650
	105		2.80	+2 -1 +1									
	112	35		+2 -1 +1		9.20	+4 +2 +1	80.0	92.0	60	91.2	92.5	690
E	119		4.10	+2 -1 +1									
	120				25		+4 +3 +1	80.0	93.0	57	91.6	93.0	630
	121		6.60	+2 +1 +1									
	128	30		+3 +1 +1		16.7	+4 +3 +1	81.0	93.0	60	92.4	93.5	620
E	135		7.00	+3 +1 +1									
	136				25		+4 +3 +1	81.5	94.0	58	92.6	93.6	930
	137		10.6	+3 +1 +1									
	144	35		+3 +1 +1		19.9	+4 +4 +2	82.0	94.0	60	92.8	93.7	800
E	151		10.0	+3 +1 +1									
	152				20		+4 +4 +2	82.5	95.0	59	93.0	93.9	840
	153		16.0	+3 +2 +1									
	160	35		+3 +2 +1		30.3	+4 +5 +2	82.5	94.5	60	93.2	94.1	760
E	167		20.8	+3 +2 +1									
	168				25		+4 +5 +2	83.0	95.0	60	93.4	94.1	950
	169		38.0	+3 +2 +1									
	176	25		+3 +3 +1			+4 +5 +2	83.5	95.5	61	93.7	94.3	885
E	183		25.2	+3 +3 +1									
	184				20		+5 +5 +2	85.0	97.0	61	95.0	96.9	805
	185		50.8	+3 +3 +1									
	192	30		+3 +3 +1		37.3	+5 +5 +2	85.0	98.5	58	97.2	98.3	840
E	199		51.9	+4 +3 +1									
	200				15		+5 +5 +2	86.0	99.0	60	98.6	99.1	
	201		42.7	+5 +5 +2									
	208	25		+5 +5 +2		78.8	+5 +5 +2	86.5	99.5	60	99.5	99.8	900
E	215		65.9	+5 +5 +2	15								
	216						+5 +5 +2	87.0	100.5	61	100.1	100.5	755
	217		61.5	+5 +6 +2									
	224	30		+5 +6 +2		59.7	+5 +5 +2	87.5	100.5	60	100.8	100.8	840
E	231		62.3	+5 +6 +2									
	232				5		+5 +5 +2	89.0	103.5	58	103.4	103.9	565
	233		68.5	+5 +6 +2									
	240	25		+5 +6 +2		75.4	+5 +5 +2	89.0	103.5	58	104.6	103.9	530

Visible sweat on forehead of subject No 4.

Slight visible sweat on forehead of subject No 6.

Heavy perspiration on forehead of subject No 6

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 2. Step-Climbing
Subject No. 6. Resting.
Relative humidity approximately 60%

	TIME (mins)	SUBJECT NO:- 2 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS^{-1}×10^{-6}	THERMAL SENSATIONS H. M. F.	SUBJECT NO:- 6 CRAMPTON INDEX	FOREHEAD SKIN CONDUCTIVITY OHMS^{-1}×10^{-6}	THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B. °F	D.B. °F	R.H. %	GLOBE THERMO. °F	SILVERED THERMO. °F	AIR VEL. ft/min
	-20	60	2.00	-2 -1 -2			-1 -1 -2	58.0	68.5	57	65.8	66.8	060
	-15			-2 -1 -2	75	1.00		58.0	67.5	57	66.1	66.8	440
	-5	60	3.60	-1 -1 -2			-1 -1 -1	57.0	68.0	57	67.1	67.2	480
	ZERO		3.60			4.40							
E	+7		3.40	-1 -1 -2									
	8				70		-2 -1 -1	61.0	69.0	63	68.2	68.6	460
	9		1.51	-1 -1 -1									
	16	60	2.00	-1 -1 -1		3.80	-1 -1 -2	61.5	69.5	63	68.9	69.0	500
E	23			-1 -1 -1									
	24				70		-1 0 -1	66.0	73.0	67	69.9	72.8	500
	25		1.80	-1 -1 -1									
	32	50		-1 -1 -1		4.00	-1 0 0	67.0	71.0	82	71.1	70.5	410
E	39		1.87	-1 -1 -1									
	40				70		-1 0 -2	68.0	74.0	74	71.1	72.1	480
	41		1.65	-1 -1 -1									
	48	45		0 -1 0		2.72	0 0 +1	71.5	79.5	68	74.4	77.9	520
E	55		1.75	0 0 0									
	56				65		0 +1 +1	75.0	82.0	65	77.7	80.7	540
	57		2.66	0 0 0									
	64	50		+1 0 0		3.40	0 +1 +1	75.5	84.0	61	80.7	82.8	600
E	71		3.20	+1 0 0									
	72				60		+1 +1 +1	75.5	84.5	63	82.3	84.2	580
	73		2.80	+1 0 +1									
	80	25		+1 +1 +1		3.80	+1 +1 +1	74.0	86.0	57	84.2	85.6	580
E	87		2.92	+1 +1 +1									
	88				60		+1 0 +1	74.0	86.0	57	84.5	86.2	550
	89		3.20	+2 +1 +1									
	96	15		+1 +1 +1		4.20	+2 +1 +1	74.0	80.0	57	84.4	85.0	520
E	103		5.40	+2 +1 +1									
	104				50		+2 +1 +2	75.5	85.5	57	82.2	85.4	590
	105		6.00	+2 +2 +1			+2 +1 +1						
	112	20		+2 +1 +1		5.20	+2 +1 +1	74.0	87.0	54	85.3	86.0	580
E	119		2.40	+2 +2 +1									
	120				45		+2 0 +1	74.0	87.0	54	86.0	86.6	610
	121		5.60	+2 +2 +1			+2 +1 +0						
	128	20		+2 +2 +1		4.00	+2 +0 +1	76.0	86.5	59	86.2	86.4	540
E	135		5.60	+2 +2 +1									
	136				35		+2 +1 +1	76.0	87.0	58	86.3	86.6	580
	137		6.00	+2 +2 +1									
	144	20		+2 +2 +1		5.80	+2 +1 +1	76.0	87.0	58	86.3	86.6	500
E	151		5.20	+2 +2 +1									
	152				30		+2 +1 +2	77.5	87.5	64	86.4	86.9	500
	153	-	5.80	+2 +2 +1									
	160	0		+2 +2 +1		6.20	+2 +1 +2	77.5	87.5	64	86.5	86.1	510
E	167		5.20	+2 +2 +1			+2 +1 +2						
	168				30		+2 +1 +2	76.0	87.5	60	86.6	86.8	510
	169		9.60	+2 +2 +2									
	176	0		+2 +2 +2		4.00	+2 +1 +2	76.5	87.5	61	87.4	86.8	460
E	183		10.2	+2 +2 +2									
	184				30		+2 +1 +2	78.0	90.0	54	90.0	90.6	425
	185		15.4	+3 +2 +2									
	192	-10		+3 +3 +2		4.40	+2 0 +1	79.0	91.0	60	93.5	92.4	400
E	199		17.4	+3 +4 +2									
	200				20		+2 +1 +2	79.5	91.5	63	94.6	93.1	360
	201		23.6	+4 +5 +2									
	208	-10		+3 +4 +2		3.60	+2 +1 +2	79.5	92.0	62	95.6	93.5	465
E	215		20.2	+4 +4 +2									
	216				25		+2 +1 +2	80.0	92.5	59	96.0	94.0	580
	217		27.3	+4 +5 +2		1							
	224	-15		+4 +5 +2		12.4	+3 +1 +2	81.5	95.0	56	98.3	93.6	365
E	231		41.0	+4 +4 +2	5								
	232						+2 +1 +2	82.5	96.0	56	101.2	96.2	550
	233		48.6	+4 +5 +2									
	240	-15	38.6	+4 +5 +2		26.2	+3 +1 +2	83.5	97.0	56	102.9	99.2	390

NOTES.

Subject No. 2 exercising for [illegible] minute periods.
Time of commencing exercise indicated by "E" on extreme left of table.

Visible sweat on forehead of Subject No. 2.

CONTROLLED LABORATORY EXPERIMENTS

Subject No. 3. Step-Climbing
Subject No. 5. Resting.
Relative humidity approximately 60%

	TIME (MINS)	SUBJECT NO. 3 CRAMPTON INDEX	SUBJECT NO. 3 FOREHEAD SKIN CONDUCTIVITY OHMS^{-1}x10^{-6}	SUBJECT NO. 3 THERMAL SENSATIONS H. M. F.	SUBJECT NO. 5 CRAMPTON INDEX	SUBJECT NO. 5 FOREHEAD SKIN CONDUCTIVITY OHMS^{-1}x10^{-6}	SUBJECT NO. 5 THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B. °F	WHIRLING HYGROMETER D.B. °F	R.H. %	GLOBE THERMO. °F	SILVERED THERMO. °F	AIR VEL. ft/min
	-20	75		-3 -1 -1			-3 -2 -1	53.5	63.5	51	64.7	63.4	[illegible]
	-15			-3 -1 -1	95		-3 -2 -1	54.0	65.0	48	64.8	64.4	[illegible]
	-5	65	1.40			1.64		55.5	66.0	51	65.0	65.5	[illegible]
	ZERO			-2 -1 -1	95		-3 -1 -1	56.5	66.5	54	[illegible]	66.4	[illegible]
E	+7		4.20	-2 -1 -1									
	8				90		-4 -1 -1	58.0	68.0	55	66.7	66.7	[illegible]
	9		1.87	-1 -1 -1									
	16	55		-1 -1 -1		1.64	-3 -1 -1	58.5	68.0	57	67.4	67.7	445
E	23		3.62	-1 -1 -1									
	24				90		-2 -1 -1	62.0	73.0	54	[illegible]	71.7	[illegible]
	25		3.82	0 -1 0									
	32	55		+1 0 0		3.40	-2 -1 -1	64.5	71.5	50	72.0	[illegible]	550
E	39		3.00	+1 +1 0									
	40				90		-1 -1 -1	66.5	72.5	50	[illegible]	[illegible]	[illegible]
	41		[illegible]	+1 +1 0									
	48	45		+2 +1 0		10.2	1 1 0	66.5	72.0	[illegible]	77.4	72.0	460
E	55		4.10	+1 +1 0									
	56				90		1 1 0	66.0	72.5	52	[illegible]	72.5	540
	57		3.00	+1 +1 0									
	64	40		+1 0 0		[illegible]	-1 -1 0	65.5	77.5	[illegible]	77.7	77.5	[illegible]
E	71		3.40	+1 0 0									
	72				90		-1 -1 0	65.0	76.5	54	77.7	77.0	[illegible]
	73		5.40	0 0 0									
	80	40		+1 0 0		3.20	-1 1 0	67.0	77.0	54	77.5	[illegible]	[illegible]
E	87		4.60	+1 0 0									
	88				85		0 -1 0	67.5	84.0	47	80.5	[illegible]	[illegible]
	89		3.60	+2 +1 +1									
	96	30		+1 0 0		16.4	0 -1 0	70.0	85.0	41	[illegible]	85.0	540
E	103		5.00	+1 0 0									
	104				85		0 -2 0	71.5	86.0	47	[illegible]	86.4	[illegible]
	105		81.0	+1 0 0									
	112	20		+1 0 0		4.40	0 -2 0	72.0	81.5	48	[illegible]	81.4	[illegible]
E	119		6.52	+1 0 0									
	120				80		0 -2 0	72.5	81.5	47	[illegible]	[illegible]	[illegible]
	121		7.00	+1 +1 0									
	128	25		+1 0 0		4.40	+1 -2 0	74.0	81.0	54	[illegible]	[illegible]	[illegible]
E	135		12.4	+1 0 0									
	136				85		+1 -1 0	75.0	81.5	50	[illegible]	[illegible]	[illegible]
	137		9.40	+1 0 0									
	144	20		+2 0 0		4.40	+1 -2 0	75.5	88.0	51	[illegible]	[illegible]	500
E	151		13.5	+1 0 0									
	152				80		+1 -2 +1	76.0	81.5	57	81.2	[illegible]	455
	153		22.8	+1 0 0									
	160	20		+2 +1 0		15.1	+1 -2 0	76.5	88.0	57	81.2	81.8	[illegible]
E	167		21.2	+2 +1 0									
	168				80		+1 -2 0	77.0	88.0	61	81.4	81.1	510
	169		49.0	+2 +1 0									
	176	15		+2 +1 0		10.6	+1 -2 0	77.0	88.0	61	87.5	88.0	550
E	183		40.0	+2 +3 +1									
	184				75		+2 -2 +1	79.0	91.0	60	84.7	91.0	425
	185		64.0	+2 +3 +1									
	192	10		+3 +3 +1			+2 -2 +1	80.0	92.0	60	93.2	92.6	440
E	199		85.0	+4 +3 +1									
	200				65		+2 -2 +1	80.5	92.5	60	95.7	94.1	465
	201		108	+4 +4 +1									
	208	15	91.7	+4 +4 +1		7.78	+3 -1 +1	81.0	92.5	62	96.2	94.4	445
E	215		91.7	+5 +5 +1									
	216		"		55		+4 0 +1	82.0	94.0	60	97.1	95.0	425
	217		91.7	+5 +5 +2									
	224	15		+5 +5 +2		19.5	+5 +2 +1	83.0	95.0	60	97.8	96.1	360
E	231		116.0	+6 +5 +2									
	232				40		+5 +4 +1	84.0	97.0	59	102.2	99.2	355
	233		120	+6 +5 +2									
	240	10		+6 +5 +2		15.6	+5 +4 +2	85.5	98.5	60	103.8	99.9	380

NOTES.

Subject No. 3 exercising for two minute periods. Time of commencing exercise indicated by "E" on extreme left of table.

Visible sweat appeared on forehead of Subject No. 3.

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 4. Step-Climbing
Subject No. 2. Resting.
Relative humidity approximately 60%

	Time	Subject No. 4 Crampton Index	Subject No. 4 Forehead Skin Conductivity $ohms^{-1} \times 10^{-6}$	Subject No. 4 Thermal Sensations H. M. F.	Subject No. 2 Crampton Index	Subject No. 2 Forehead Skin Conductivity $ohms^{-1} \times 10^{-6}$	Subject No. 2 Thermal Sensations H. M. F.	Whirling Hygrometer W.B. °F	Whirling Hygrometer D.B. °F	R.H. %	Globe Thermo. °F	Silvered Thermo. °F	Air Vel. ft/min	Notes
	-20	85	6.68	-2 -2 -2	50	3.08	-3 -2 -2	54.0	61.5	60	66.5	66.9	485	Subject No. 4 exercising for ten minute periods. Time of commencing exercise indicated by "E" in column left of table.
	-5	85		-3 -2 -2			-3 -2 -2	51.0	66.5	56	66.2	65.6	465	
	Zero		5.25	-3 -2 -2		1.28	-3 -2 -2	51.0	66.5	56	66.2	65.9	410	
E	+1		10.8	-3 -2 -2										
	8				50			50.0	67.0	59	66.3	68.0	510	
	9		4.35	-3 -2 -2										
	16	65		-3 -2 -2		3.15	-3 -2 -2	61.0	67.0	63	68.3	68.8	605	
E	23		6.85	-2 -2 -2										
	24						-3 -2 -2	61.5	76.0	64	71.5	75.4	540	
	25		5.60	-1 -2 -2										
	32	65		0 -1 -2		3.14	-1 -1 -1	61.0	78.0	64	74.0	77.3	660	
E	39		4.00	0 -1 -2										
	40				50		-1 -1 -1	71.5	80.5	65	77.8	80.4	620	
	41		4.20	+1 -1 -1										
	48	60		+1 -1 -1		3.63	-1 -1 -1	72.5	82.0	63	79.0	81.2	610	
E	55		4.45	+2 0 0										
	56				45		0 -1 0	73.0	82.0	65	80.8	81.7	630	
	57		12.5	+3 0 0										
	64	50		+2 0 0		4.05	0 0 0	72.5	82.0	63	80.7	81.2	500	
E	71		8.10	+2 0 0										
	72				50		+1 0 0	72.5	81.5	65	80.8	81.3	450	
	73		8.10	+3 0 0										
	80	45				4.05	+1 0 0	73.5	84.0	61	81.9	81.4	560	
E	87		12.15	+2 0 +1										
	88				40		+1 0 +1	74.0	85.0	60	82.8	84.2	640	
	89		24.8	+4 0 +1										Visible sweat on forehead of subject No. 4.
	96	35		+4 +1 +1		3.40	+2 0 0	74.0	85.0	60	82.6	84.5	520	
E	103		88.7	+4 +1 +1										
	104				35		+2 0 +1	75.0	86.0	60	84.3	85.4	700	
	105		45.8	+4 +2 +1										
	112	30		+4 +2 +1		3.34	+2 0 +1	76.0	86.0	60	84.9	85.4	560	
E	119		40.5	+4 +3 +1										
	120				30		+2 0 +1	75.0	86.0	60	85.2	86.0	620	
	121		52.5	+5 +3 +1										
	128	30		+4 +3 +1			+2 0 +1	75.5	87.0	59	85.6	86.2	560	
E	135		35.8	+4 +3 +1										
	136				25		+1 0 +1	75.5	87.0	59	85.8	86.4	570	
	137		54.0	+5 +4 +1										
	144	25		+5 +4 +1		5.40	+2 0 +1	76.0	87.0	61	86.1	86.6	520	
E	151		45.8	+5 +4 +1										
	152				25		+2 0 +1	76.0	87.5	60	86.2	87.0	520	
	153		60.6	+5 +4 +1										
	160	10		+5 +4 +1			+1 0 +1	75.0	86.5	60	86.1	86.2	600	
E	167		54.1	+4 +4 +1										
	168				20		+1 0 +1	76.0	87.0	61	86.1	86.9	610	
	169		52.4	+5 +4 +1		2.13								
	176	20		+4 +4 +1			+1 0 +1	76.0	87.0	61	86.4	86.8	570	
E	183		52.0	+5 +4 +2		4.50								
	184				15		+2 0 +1	78.0	90.0	59	90.4	90.8	410	
	185		60.7	+5 +4 +2										
	192	15		+5 +4 +2		1.65	+3 +1 +1	78.5	90.5	59	92.6	91.6	435	
E	199		81.5	+5 +4 +2										
	200				10		+3 +1 +1	79.0	91.0	59	93.1	92.2	450	
	201		84.0	+5 +4 +2										
	208	5		+5 +4 +2		6.22	+3 +2 +1	80.0	92.0	60	95.0	93.2	450	
E	215		97.5	+5 +4 +2										
	216				10		+3 +2 +1	80.5	92.5	60	95.5	93.8	445	
	217		97.0	+5 +4 +2										
	224	0		+5 +4 +2		11.2	+4 +2 +1	82.0	94.0	60	96.8	95.4	310	
E	231		106.0	+5 +4 +2										
	232				5		+4 +2 +1	84.0	96.5	60	100.6	98.0	360	
	233		92.6	+6 +4 +2										
	240	10		+6 +4 +2		22.9	+4 +2 +1	85.0	97.5	60	102.3	98.8	400	

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 4. Step-Climbing
Subject No. 6. Resting.
Relative humidity approximately 80%

	TIME (MINS)	SUBJECT NO:- 4 CRAMPTON INDEX	SUBJECT NO:- 4 FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	SUBJECT NO:- 4 THERMAL SENSATIONS H. M. F.	SUBJECT NO:- 6 CRAMPTON INDEX	SUBJECT NO:- 6 FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁻⁶	SUBJECT NO:- 6 THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B °F	WHIRLING HYGROMETER D.B. °F	RH %	GLOBE THERMO. °F	SILVERED THERMO °F	AIR VEL. ft/min	NOTES
	-20	60	4.00	0 -1 0			0 -1 +1	72.5	78.5	75	72.8	77.7	880	Subject No. 4 exercising for two minute periods. Line of commencing exercise indicated by "E" on outside left of table.
	-15			0 0 +1	65		0 -1 +1	74.0	81.0	72	75.2	79.8	565	
	-5	55		+1 0 +1			0 0 0	75.5	82.5	73	79.4	82.0	520	
	ZERO			+1 0 +1	70	7.60	0 0 0	75.5	78.0	89	80.5	82.8	560	
E	+7		6.00	+1 0 +1										
	8				70		+1 0 +1	77.5	84.5	73	82.4	84.2	515	
	9		12.2	+1 0 +1										
	16	40		+2 0 +1		5.60	+1 0 +1	78.5	86.0	72	83.8	82.5	505	
E	23		7.40	+2 0 +1										
	24				75		+1 0 0	79.5	87.5	71	85.2	86.3	615	
	25		12.40	+3 +1 +1										
	32	40		+3 +2 +1		5.15	+1 0 +1	80.0	87.5	73	86.3	87.3	515	
E	39		16.00	+3 +2 +1										
	40				75		+1 0 +1	80.0	88.0	71	86.9	87.8	595	
	41		26.2	+4 +3 +1										
	48	55		+3 +3 +1			+1 0 +1	80.0	88.5	71	87.3	88.0	635	Slight visible sweat on forehead of subject No. 4.
E	55		16.0	+3 +2 +1										
	56				75		+1 0 +1	78.0	84.0	77	86.0	82.8	600	
	57		28.2	+3 +3 +1										
	64	55				3.00	+1 0 0	77.0	80.5	86	83.2	80.4	450	
E	71		18.4	+3 +2 +1										
	72			+3 +2 +1	80		0 0 0	78.0	84.0	77	81.8	83.3	515	
	73		30.7	+4 +3 +1										
	80	50		+3 +3 +1			+1 0 +1	80.5	90.0	67	85.0	88.3		
E	87		22.4	+3 +3 +1										
	88				75		+1 0 +1	82.0	90.0	71	87.0	90.7	510	
	89		46.7	+3 +4 +1										
	96	45		+3 +3 +1		10.60	+1 0 +1	82.5	90.5	71	88.1	89.8	535	
E	103		48.4	+3 +3 +1										
	104				75		+1 0 +2	83.0	91.0	72	89.2	90.3	600	
	105		35.8	+4 +3 +1										
	112	25		+3 +3 +1		6.80	+1 0 +1	82.5	91.0	72	89.8	90.4	435	Subject No. 4 complains of slight headache on climbing
E	119		45.0	+3 +3 +1										
	120				70		+2 0 +1	83.5	91.5	72	90.2	91.0	550	
	121		41.6	+4 +4 +2										
	128	30		+3 +3 +2		5.20	+1 0 +1	83.5	91.5	72	90.6	91.4	515	
E	135		58.8	+3 +3 +2										
	136				70		+2 0 +2	84.0	92.0	72	91.0	91.7	540	
	137		62.4	+4 +4 +2										
	144	30		+3 +4 +2		6.91	+2 0 +2	84.5	92.5	72	91.3	92.0	465	
E	151		75.3	+3 +4 +2										
	152				65		+2 +1 +2	85.0	93.0	72	91.7	92.2	950	
	153		78.0	+4 +4 +2										
	160	30		+4 +4 +2		12.05	+2 +2 +2	85.5	93.0	74	91.9	92.5	615	
E	167		61.5	+4 +4 +2										
	168				55		+4 +2 +2	87.0	93.5	77	92.4	93.5	570	
	169		80.8	+5 +5 +2										
	176	15		+5 +5 +2		34.64	+4 +3 +2	87.0	94.0	76	92.8	93.5	805	Slight visible sweat on forehead of Subject No. 6.
E	183		104.7	+5 +5 +2										
	184				55		+4 +5 +2	88.5	95.0	77	93.5	94.4	700	
	185		104.7	+6 +5 +2										
	192	15		+6 +5 +2			+5 +5 +2	89.5	96.0	77	94.0	95.0	680	
E	199		94.5	+6 +5 +2	30									
	200						+5 +5 +2	90.0	96.5	78	94.6	95.2	750	
	201		134.0	+6 +5 +2										
	208	5	103.0	+5 +5 +2		39.9	+5 +5 +2	90.0	96.0	79	95.0	95.8	715	Subject No. 4 had glass of water.
E	215			+5 +5 +2										
	216				35		+5 +5 +2	91.5	98.0	78	95.8	96.8	600	
	217			+6 +5 +2										
	224	5	106.0	+5 +5 +2		73.7	+5 +6 +2	91.5	98.0	78	96.2	97.3	810	
E	231			+5 +5 +2										
	232		1.		25		+5 +6 +2	92.0	98.5	80	96.8	97.8	760	
	233		107.0	+6 +5 +2										
	240			+6 +6 +2		61.5	+5 +6 +2	93.0	98.5	83	97.3	98.2	720	

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 5. Step-Climbing
Subject No. 4. Resting.
Relative humidity approximately 80%

	TIME (MINS)	SUBJECT No:- 5 KAMPMON INDEX	SUBJECT No:- 5 FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁶	SUBJECT No:- 5 THERMAL SENSATIONS H. M. F.	SUBJECT No:- 4 KAMPMON INDEX	SUBJECT No:- 4 FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹×10⁶	SUBJECT No:- 4 THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B. °F	WHIRLING HYGROMETER D.B. °F	R.H. %	GLOBE THERMO. °F	SILVERED THERMO. °F	AIR VEL. ft/min	NOTES.
	-20	60		0 -1 0			-1 -1 0	64.0	70.5	70	67.8	69.0	410	Subject No.5 exercising for two minute periods. Time of commencing exercise indicated by "E" on extreme left of table.
	-15			-1 -1 -1	60		-1 -1 0	63.0	69.0	72	68.5	68.4	345	
	-5	65		-1 -1 -1			-1 1 0	64.0	69.0	71	68.8	68.8	500	
	ZERO			-2 -1 -1	55	7.20	-2 -1 0	64.5	70.0	75	69.0	69.2	580	
E	+1			-2 -1 -1			-2 -1 0							
	8				60		-2 -1 -1	65.0	70.0	77	69.5	69.6	520	
	9		2.87	-1 -1 -1										
	16	65		-1 -1 -1		9.45	-2 -1 -1	65.0	70.0	77	70.0	70.2	760	
E	23		4.41	-1 -1 0										
	24				55		-1 -1 0	72.5	77.0	81	71.7	75.0	465	
	25		6.00	0 0 0										
	32	65		0 0 +1		9.80	0 0 0	75.0	78.5	85	76.0	78.2	550	
E	39		3.74	0 0 +1										
	40				55		0 0 0	74.5	76.5	91	77.4	76.2	430	
	41		5.60	0 0 +1										
	48	70		+1 0 +1		11.4	+1 +1 +1	76.0	80.8	83	77.4	78.8	415	
E	55		4.60	+1 +1 +1										
	56				50		+2 +1 +1	78.0	83.5	78	77.6	82.9	445	
	57		5.30	+2 +1 +1										
	64	55		+2 +3 +1		7.80	+3 +2 +1	79.0	85.0	77	83.0	85.4	720	
E	71		5.00	+2 +3 +1										
	72				45		+3 +2 +1	80.0	87.0	74	84.8	86.8	560	
	73		6.40	+2 +3 +2										
	80	45		+3 +3 +2		14.0	+3 +2 +1	81.0	88.0	74	86.8	88.0	400	
E	87		4.00	+3 +3 +2										
	88				40		+3 +2 +1	81.0	89.0	71	87.8	88.9	540	
	89		4.95	+4 +4 +2										
	96	45		+3 +4 +2		22.6	+3 +3 +1	82.0	89.5	73	88.6	89.6	680	Visible sweat on forehead of Subject No.4.
E	103		2.80	+3 +4 +2										
	104				40		+3 +3 +1	82.0	90.0	71	89.1	90.3	100	
	105		8.40	+4 +4 +2										
	112	40		+3 +4 +2		61.6	+4 +3 +1	82.5	90.5	71	89.6	90.6	620	
E	119		5.61	+4 +4 +2										
	120				25		+4 +4 +1	83.0	91.5	72	90.0	90.9	550	
	121		15.2	+4 +4 +2										
	128	35		+3 +4 +2		39.8	+4 +4 +2	84.0	91.5	74	90.7	91.7	860	
E	135		20.4	+4 +4 +2										
	136				25		+5 +4 +2	85.5	92.5	75	91.2	92.3	445	
	137		17.8	+4 +4 +2										
	144	35		+4 +4 +2		71.1	+5 +5 +2	85.5	91.0	80	91.9	92.5	465	
E	151		23.6	+4 +4 +2										Visible sweat on forehead of Subject No.5.
	152				25		+5 +5 +2	85.5	91.0	80	91.4	90.9	425	
	153		26.8	+5 +4 +2										
	160	30		+4 +4 +2			+5 +4 +2	83.5	89.5	78	89.2	88.8	410	
E	167		23.4	+4 +4 +2		59.4								
	168				20		+5 +4 +2	86.5	91.5	82	90.6	91.8	500	
	169		32.4	+4 +5 +2										
	176	30		+4 +5 +2		58.8	+5 +4 +2	86.5	91.5	82	90.8	90.8	565	
E	183		28.6	+4 +5 +2										
	184				20		+5 +4 +2	87.0	92.0	82	90.8	92.0	480	
	185		60.7	+5 +5 +2										
	192	5		+5 +5 +2		19.0	+5 +4 +2	88.5	94.5	79	92.1	93.5	485	
E	199		34.7	+5 +5 +2										
	200				20		+5 +4 +2	89.5	95.5	79	93.4	95.0	360	
	201		39.9	+6 +5 +2										
	208	10		+6 +5 +2		16.2	+5 +5 +2	90.5	96.5	79	94.9	96.5	455	
E	215		51.2	+5 +5 +2										
	216				15		+5 +5 +2	91.5	97.5	80	95.7	97.4	560	
	217		71.0	+6 +5 +2										
	224	5		+6 +5 +2		69.4	+5 +5 +2	91.5	97.0	81	96.5	98.2	505	
E	231		82.0	+6 +5 2										Subject No.5 hyperventilating.
	232				5		+5 +5 +2	92.5	98.5	80	97.1	98.6	690	
	233		70.0	+6 +5 +2										
	240	-10		+6 +5 +2		86.6	+5 +5 +2	93.0	99.0	80	97.6	99.0	740	Subject No.5. Syncope.

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 3. Step-Climbing.
Subject No. 2. Resting.
Relative humidity approximately 80%

	Subject No. 3				Subject No. 2			Whirling hygrometer						
	Time (mins)	Lampton index	Forehead skin conductivity [illegible]	Thermal sensations H. M. F.	Lampton index	Forehead skin conductivity [illegible]	Thermal sensations H. M. F.	W.B. °F	D.B. °F	R.H. %	Globe thermo °F	Shielded thermo °F	Air vel. ft/min	Notes
	20	60		-1 0 0			-2 -1 -2	65.0	64.0	81	64.3	64.4	420	Subject was exercising for two minute intervals. Time of commencing exercise indicated by "E" in column [illegible] of table.
	15			-1 0 0	60		-2 -1 -2	65.5	64.0	83	64.5	64.0	500	
	5	55		-1 0 0		2.17	-2 -1 -2	65.5	64.0	85	64.6	64.3	600	
	[illegible]		1.87	-1 0 0	60			67.0	70.5	84	69.7	69.7		
E	1		1.65	-1 0 0										
	8				55		-2 -1 -2	70.0	76.0	78	70.8	73.3	410	
	9		1.87	-1 0 0										
	16	55		-1 0 0		3.80	-1 -1 -2	67.5	73.0	84	72.8	73.3	440	
E	23		2.10	-1 0 0										
	24				55		-2 -1 -2	72.0	77.5	77	75.2	74.4	410	
	25		3.66	-1 0 0										
	32	50		0 +1 0		3.66	-2 -1 -2	75.0	81.5	74	76.5	77.8	440	
E	39		3.45	+1 0 0										
	40				50		-1 -1 1	76.0	81.5	78	74.8	81.5	500	
	41		4.60	+1 0 0										
	48	45		+1 0 0		7.22	-1 -1 -1	77.5	82.0	82	80.4	81.5	520	
E	55		4.41	+1 0 0										
	56				50		0 -1 -1	78.5	84.0	77	81.5	82.5	525	
	57		5.15	+1 0 0										
	64	35		+1 0 0		5.60	0 0 -1	80.0	86.5	76	84.1	86.5	620	
E	71		6.76	+1 0 0										
	72				50		0 0 -1	80.0	85.5	77	85.0	85.2	560	
	73		3.66	+1 0 0										
	80	35		+1 +1 0		4.11	+1 0 -1	79.5	85.0	77	84.4	85.0	600	
E	87		4.10	+1 +1 0										
	88				50		+1 0 -1	80.0	86.5	76	84.4	85.4	560	
	89		6.55	+1 +1 +1										
	96	25		+1 +1 +1		5.80	+1 0 -1	82.5	89.0	76	86.8	88.7	600	
E	103		7.13	+1 +1 +1										
	104				40		+1 +1 0	83.0	90.0	75	88.4	90.4	620	
	105		14.0	+2 +1 +1										
	112	20		+2 +2 +1		5.41	+1 +1 0	85.0	92.0	75	89.7	91.4	540	
E	119		22.7	+2 +2 +1										Visible sweat on forehead of subject No. 3.
	120				30		+1 +1 0	86.0	92.0	78	91.0	93.2	560	
	121		45.8	+3 +2 +2										
	128	15		+2 +2 +1		8.50	+1 +1 +1	85.0	90.0	81	91.0	90.5	500	
E	135		64.5	+3 +3 +2										
	136				20		+1 +1 +1	85.0	90.0	81	90.3	90.0	575	
	137		61.5	+4 +4 +2										
	144	15		+4 +4 +2		5.30	+2 +1 +1	86.0	91.5	80	90.0	90.8	520	
E	151		76.2	+4 +4 +2										
	152				25		+2 +1 +1	87.0	93.0	79	90.7	92.8	620	
	153		11.0	+4 +5 +2										
	160	10		+4 +5 +2		6.10	+3 +2 +1	88.0	94.0	79	92.7	94.3	600	
E	167		86.6	+5 +5 +2										
	168				5		+3 +3 +2	89.0	95.0	77	95.5	96.0	540	
	169		18.0	+5 +5 +2										
	176	5	104.0	+5 +5 +2		10.4	+4 +3 +2	90.0	95.5	81	94.2	95.8	580	
E	183		90.1	+5 +5 +2										
	184				10		+4 +4 +2	90.5	96.5	79	94.9	96.4	610	
	185		84.2	+5 +5 +2										
	192	0	75.5	+5 +5 +2		23.9	+4 +4 +2	90.0	94.5	84	94.8	96.8	500	Visible sweat on forehead of subject No. 2.
E	199		70.2	+5 +5 +2										
	200				10		+4 +5 +2	91.0	96.5	81	95.1	96.9	550	
	201		90.0	+6 +6 +2										
	208	-10	104.0	+6 +6 +2		34.1	+5 +5 +2	92.0	97.5	82	96.0	97.6	600	

CONTROLLED LABORATORY EXPERIMENTS
Subject No. 6. Step-Climbing
Subject No. 5. Resting.
Relative humidity approximately 80%

	TIME (MINS)	SUBJECT No:- 6 LEAMINGTON INDEX	SUBJECT No:- 6 FOREHEAD SKIN CONDUCTIVITY OHMS⁻¹x10⁻⁶	SUBJECT No:- 6 THERMAL SENSATIONS H. M. F.	SUBJECT No:- 5 LEAMINGTON INDEX	SUBJECT No:- 5 FOREHEAD SKIN CONDUCTIVITY	SUBJECT No:- 5 THERMAL SENSATIONS H. M. F.	WHIRLING HYGROMETER W.B °F	WHIRLING HYGROMETER D.B °F	R.H. %	GLOBE THERMO. °F	SILVERED THERMO. °F	AIR VEL. ft/min	NOTES
	-20	65		-1 0 -1			-2 -1 0	61.5	70.5	86	69.8	72.3	405	
	-15			-1 0 -1	80		-2 -1 -1	61.5	70.5	86	70.4	69.9	410	
	-5	60		-1 0 -1			-2 -1 -1	68.0	71.0	86	70.4	70.1	450	
	[illegible]			-1 0 +1	75	5.40	-2 -1 0	70.0	73.5	84	70.8	72.8	415	
E	7		2.40	-1 +1 0										
	8				80		-2 0 0	71.5	76.5	79	73.2	75.5	485	
	9		2.57	1 +1 0										
	16	60		-1 0 0		4.65	-2 0 0	71.0	75.0	82	74.4	74.0	405	
E	23		1.75	0 +1 0										
	24				75		-1 0 0	73.5	80.5	72	76.2	79.1	460	
	25			+1 +1 0										
	32	50		+1 +1 0		5.12	+1 0 0	73.5	79.0	77	78.4	81.0	510	
E	39		2.60	+1 +1 0										
	40				75		0 0 0	73.5	77.5	83	78.8	77.2	575	
	41		4.12	+1 +1 0										
	48	50		+1 +1 0		4.45	-1 0 0	73.0	76.0	87	77.2	75.6	445	
E	55		3.20	0 +1 0										
	56				75		-2 0 0	73.0	76.0	87	76.3	75.1	555	
	57		4.80	0 +1 0										
	64	55		0 +1 0		2.72	-3 0 0	73.0	75.5	89	75.7	75.0	425	
E	71		12.17	0 +1 0										
	72				75		-4 0 0	73.0	75.5	89	75.5	74.6	500	
	73		5.50	0 +1 0										
	80	60		0 +1 0		3.51	-3 0 0	73.0	75.5	89	75.3	74.7	405	
E	87			0 +1 0										
	88				85		-3 0 0	73.0	76.0	87	75.6	75.2	410	
	89			0 +1 0										
	96	65		+1 +1 0		3.48	-3 0 0	74.5	78.5	83	75.7	76.8	430	
E	103		3.00	+1 +1 0										
	104				85		0 0 0	78.0	83.5	78	78.8	82.2	560	
	105		4.60	+1 +1 0										
	112	30		+1 +1 0		1.65	+1 0 0	79.5	85.5	77	83.0	85.1	540	
E	119		3.85	+1 +1 0										
	120				60		+1 +1 +1	81.0	87.5	76	85.2	87.0	620	
	121		5.49	+1 +1 0										
	128	20		+1 +1 0		4.40	+1 +1 +1	82.0	88.5	76	86.8	88.6	460	
E	135		3.40	+1 +1 0										
	136				55		+2 +2 +2	83.0	89.0	78	87.8	89.2	550	
	137		4.40	+1 +1 0										
	144	30		+1 +1 +1		6.95	+2 +2 +2	84.5	91.0	77	89.4	90.8	490	
E	151		4.95	+1 +1 +2										
	152				50		+2 +3 +2	86.0	92.0	78	90.7	92.2	670	
	153		27.2	+1 +1 +2										
	160	25		+2 +4 +2		4.89	+4 +3 +2	87.0	93.0	79	91.7	93.0	540	Visible sweat on forehead of Subject No. 6.
E	167		15.2	+2 +4 +2										
	168				45		+4 +4 +2	88.0	94.0	79	92.5	94.2	600	
	169		44.8	+2 +5 +2										
	176	25		+3 +5 +2		4.20	+4 +4 +2	88.5	94.5	79	93.2	94.5	540	
E	183		54.0	+3 +5 +2										
	184				35		+4 +4 +2	89.5	95.5	79	94.0	95.4	600	
	185		64.3	+4 +5 +2										
	192	5		+4 +6 +2		15.6	+4 +4 +2	90.0	96.0	79	94.7	96.0	510	
E	199		73.5	+4 +6 +2										
	200				35		+4 +4 +2	90.5	96.0	81	95.3	96.5	720	
	201		85.8	+5 +6 +2										
	208	0		+4 +6 +2		22.8	+4 +5 +2	90.0	94.5	84	94.3	94.5	540	Visible sweat on forehead of Subject No. 5.
E	215		101.2	+4 +6 +2										
	216				15		+5 +5 +2	91.0	96.5	81	94.7	96.2	790	
	217		56.4	+5 +7 +2		28.4								
	224	-5		+5 +7 +2		28.4	+5 +5 +2	92.0	96.5	85	95.5	97.0	655	

NOTES.

Subject No. 6 [illegible] for two minute periods. Time of commencing exercise indicated by "E" on extreme left of table.

APPENDIX 2A.

Statistical Method Employed for Assessing the Results from the Experiments Described in Chapter 2.

The main effects and interactions may all be obtained by subtracting the sum of 4 of the treatment totals less the sum of the other 4. The actual signs are given in Table 2A.1.

TABLE 2A.1.

Combination of Treatments.

Effect	(1)	h	F	Fh	f	fh	Ff	Ffh
Total	+	+	+	+	+	+	+	+
h	-	+	-	+	-	+	-	+
F	-	-	+	+	-	-	+	+
Fh	+	-	-	+	+	-	-	+
f	-	-	-	-	+	+	+	+
fh	+	-	+	-	+	-	+	-
Ff	+	+	-	-	-	-	+	+
Ffh	-	+	+	-	+	-	-	+

The seven sums of squares for the individual treatments are then obtained by squaring these Effect values and dividing the result by 32 since it is the square of the total of ± 1 times the treatment values of each of 32 experiments.

e.g. The effect value for F (Table 2.4) is $-595.7 + 507.3 + 615.2 + 404.8 - 305.2 - 238.4 + 602.6 + 380.3 = + 356.3$.

The Sum of squares is therefore $= \frac{(356.3)^2}{32} = 3967.17$ as in Table 2.5.

(1) The Block Sum of Squares $= \sum_{1}^{4} \frac{(Sb)^2}{8} - \frac{S^2}{4x8}$ S.B. = Total for 1 block.

(2) The Treatment Sum of Squares $= \sum_{1}^{8} \frac{(St)^2}{4} - \frac{S^2}{4x8}$ S.T. = Total for 1 treatment.

(3) The Total Sum of Squares $= \sum_{1}^{32} x^2 - \frac{S^2}{4x8}$ S = Grand Total.

(4) The Error Sum of Squares = (3) - (2) - (1)

The treatment sum of squares can be checked by taking the total of the individual treatment sums of squares obtained from the use of table 2A.1. This should be equal to (2).

The analysis is then carried out in the normal way allowing 3 degrees of freedom for Block sum of squares, 7 for treatments, 19 for Error (two less than the normal number, see Appendix 2B) making a total of 29 degrees of freedom.

APPENDIX 2B

The experiments in which the fire was combined with the extractor fan as a means of ventilating the room were abandoned after only two tests for reasons which have been given in Chapter 2. Therefore the two missing values had to be estimated.

When only one result in a set is missing or abnormal it may be estimated by the following formula. (O.L. Davis, "Statistical Methods in Research and Production" p. 116).

$$K \times (n - 1)(m - 1) = (n + m - 1) \times S - n \times S_T - m \times S_B.$$

where K = estimate of missing value

n = number of treatments

m = number of blocks

S = sum of all known $(nm - 1)$ observations

S_T = sum of treatment totals, not including the treatment of which one result is missing.

S_B = sum of block totals, not including the block of which one result is missing.

Thus for $n = 8$ and $m = 4$

$$K = \frac{11S - 8S_T - 4S_B}{21.} \text{ ------------- (1)}$$

This can be simplified in the following way:-

Let B = Total for that block which includes the missing value (i.e. the total of 7 values)

t = Total for that treatment which also includes the missing value (i.e. total of 3 values)

Then $4S_T = 4S - 4B$ - - - - - - - (2)

$8S_B = 8S - 8t$ - - - - - - - (3)

Substitution in (1) gives $K = \dfrac{4B + 8t - S.}{21.}$ - - - - - (4)

However, in the analyses there were two missing values and a method of successive approximations was adopted as follows:-

(a) The mean of the two observed values, say a_1 for treatment Ff was inserted in column 3.

(b) Using a_1 and equation (4) the missing value, say b_1 was calculated for column 4.

(c) Then using b_1 a new value for column 3, say a_2 was calculated.

(d) If a_2 was not very much different from a_1 then a_2 and b_1 were used in the analysis. However if there was a considerable discrepancy the above procedure, commencing with a_2 in column 3 was repeated until consistent values were obtained.

The analysis was then carried out as in the normal case but with one exception. The number of degrees of freedom for the remainder is two less than for the normal case, owing to two results having been estimated. For the analysis of the increases in dry and wet bulb temperatures and relative humidities at the two 4 ft. levels (Positions I_2 and II_2) the Error degrees of freedom were consequently reduced from 21 to 19.